MEMORANDUM

TO: Docket Control

FROM: Elijah O. Abinah
Director
Utilities Division

DATE: September 28, 2021

RE: IN THE MATTER OF RESOURCE PLANNING AND PROCUREMENT IN 2019, 2010 AND 2021. (DOCKET NO. E-00000V-19-0034)

SUBJECT: SEPTEMBER 28, 2021, ASCEND ANALYTIC WORKSHOP PRESENTATION

Please find attached copy of the presentation that will be part of the Commission's September 28, 2021, Resource Planning and Procurement Special Open Meeting.

EOA:ZTB:yw/

Originator: Zachary T. Branum

Attachment

On this 28th day of September, 2021, the foregoing document was filed with Docket Control as a Utilities Division Memorandum, and copies of the foregoing were mailed on behalf of the Utilities Division to the following who have not consented to email service. On this date or as soon as possible thereafter, the Commission's eDocket program will automatically email a link to the foregoing to the following who have consented to email service.

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ATTACHMENT

Ascend Analytics

Better models. Better decisions.

Workshop: Modeling the Energy Rules

September 28 - 29, 2021

Ascend Analytics

- Founded in 2002 with 75 employees, headquartered in Boulder, CO
- Seven integrated software products for operations, portfolio analytics, and planning
- Consulting and custom analytical solutions

Proven and Broadly Adopted

New York Power Authority · nrg · Duke Energy · American Electric Power · Silicon Valley Clean Energy · Austin Energy · CPA · ipl an AES company · REU · TID Water & Power · Ameren · Lansing BWL · NorthWestern Energy · LADWP Los Angeles Department of Water & Power · Glendale Water & Power · 8minute Solar Energy · ISO new england · East Bay Community Energy · Nebraska Public Power District · Shell · Terra-Gen · NextEra Energy

Differentiated Value for Enhanced Decision Analysis

PowerSimm OPS
OPERATIONAL STRATEGY

- Optimal short-term dispatch
- Determine operating strategies from position and financial exposure
- Track realized customer revenue and costs to settled day ahead and real time price
- Optimize financial exposure between day ahead and real time prices

PowerSimm Portfolio Manager
PORTFOLIO MANAGEMENT

- Portfolio management
- Generation asset management
- Hydro and renewable asset modeling
- Retail management & pricing
- Energy purchases and sales
- CFaR, GMaR, EaR

PowerSimm Planner
VALUATION & PLANNING

- Asset valuation
- Resource Planning
- Capacity Expansion Planning
- Reliability Analysis
- Renewable Integration
- Long-term Price Forecasting

Smart Bidder
STORAGE OPTIMIZATION

- Optimal offers to ISO
- Continuous adjust ISO offers
- Forecast probabilities of price spikes
- Renewables plus storage

BatterySimm Valuation
STORAGE VALUATION

- Optimal siting and sizing
- Captures realistic revenues given imperfect foresight
- Battery cycle analysis

Ascend Market Intelligence

- Power, ancillary, and capacity price forecasts, including subhourly and geographic evolution
- Market reports and analysis
- Hourly and subhourly nodal and hub price simulations

Review Team: Ascend Analytics

David Millar

Director of Resource Planning Consulting

M.S., Environmental Mgmt, Energy Economics and Policy, Duke Universi
B.S., Earth Sciences, University of California Santa Cruz
B.A., Politics, University of California Santa Cruz

- Leads Ascend's resource planning consulting team, assisting utility clients advance their resource planning capabilities including choosing future portfolios across both least-cost and least-risk.
- Pioneers best RFO/RFP practices through All-Source RFPs including both supply and demand resources.
- Deep background in California electricity planning from PG&E and Lawrence Berkeley National Lab.

Brent Nelson, PhD

Manager, Forecasting and Markets

Ph.D., Mechanical Engineering – Georgia Institute of Technology
M.S., Mechanical Engineering – Georgia Institute of Technology
B.S., Mechanical Engineering – University of California - Berkeley

- Leads forecasting practice, including preparation of market reports
- Leads resource planning activities, including RFO valuation and low-carbon resource planning
- Prior to joining Ascend, was an Associate Professor of Mechanical Engineering at Northern Arizona University, held a collaborative appointment at the National Renewable Energy Laboratory, and was a AAAS Science and Technology Policy Fellow at the US Department of Energy

Anthony Boukarim

Senior Consultant

M.S., Energy Resources Engineering – Stanford University
B.S., Mechanical Engineering – American University of Beirut

- Led multiple RFO engagements with Clean Power Alliance and Peninsul Clean Energy, evaluating hundreds of renewables and storage offers
- Conducted a portfolio impact analysis for Salt River Project, assessing different wind projects and evaluating their economic and reliability values as well as the financial risk
- Assessed the benefit of geothermal in decarbonizing cost effectively baseload and studied the cost and transition to green hydrogen
- Worked on multiple impact assessment and cost benefit projects for BWP, CPS energy, SVCE and other load serving entities

Brandon Mauch, PhD

Manager, Resource Planning Analytics

Ph.D., Engineering and Public Policy – Carnegie Mellon
M.S., Mechanical Engineering – University of Wisconsin
B.S., Mechanical Engineering – University of Kansas

- Leads resource planning production activities in Ascend's consulting group providing resources planning and regulatory support and is currently managing work for NorthWestern Energy and Los Angeles Department of Water and Power, among others.
- Prior to joining Ascend, was a Senior Program Manager for CLEAResult Consulting where he managed utility energy efficiency and demand response programs for Midwestern utilities
- He was a Utility Regulation Engineer for the Iowa Utilities Board

Zach Brode

Senior Energy Analyst

M.A., Economics – University of British Columbia
B.A., Economics and Mathematics – Wheaton College (MA)

- Lead analytical process for the Indianapolis Power and Light 2019 IRP and 2020 RPF, Los Angeles Department of Water and Power, Salt River Project, and NorthWestern Energy
- Works on developing new PowerSimm features for Resource Adequacy, Capacity Expansion, and other client requested improvements

Verdant Associates

Review Team

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Co-Founder

DER program evaluation, market assessment, decarbonization, environmental impacts, cost-effectiveness

Jean Shelton, PhD
Co-Founder

Energy efficiency and demand response program evaluation, market research, cost-effectiveness, econometric modeling

Collin Elliot
Senior Principal

End-use energy impacts, econometric time-series forecasting, short term load forecasting

Mike Rufo
Strategic Advisor

Policy and market assessment, evaluation and resource planning, greenhouse gas and energy impacts. *IEPEC Lifetime Award Winner*

AGENDA

IRP Review Study

01.

Intro

Scope & Process

02.

Approach to Building Low Carbon Portfolios

Resource options, "clean firm", uncertainties

03.

Results and Interpretation

IRP review, Portfolios, Results, Implications

04.

Next Steps

Recommendations, potential for additional analysis

05.

Details for each LSE

IRP review, Portfolios, Results, Implications

Ascend's Project Scope

- Ascend was hired in compliance with Commission Decision No. 76632:
    - "It is further ordered that for all future IRPs submitted by Arizona Public Service Company, Tucson Electric Power Company, and UNS Electric, Inc., Staff shall, in addition to their existing review requirements and methods, hire one or more third-party analysts to conduct an independent review of the scenarios and portfolios presented in each IRP, and of their respective costs and benefits, and to develop and present alternative scenarios and portfolios the third-party analyst deems are not adequately represented or considered in the IRP. The hiring of a third-party analyst shall require prior Commission approval."
- Ascend independently reviewed the IRPs.
- Ascend developed and presented the following alternative portfolios for APS, TEP, and UNSE:
    - 80% carbon reductions by 2050
    - 100% carbon reductions by 2050
    - "Least Cost"

Ascend's Project Scope

- Ascend's scope of work is consistent with the requirements of Decision No. 76632:
  - Review if the IRP processes used by each LSE adhere to best practices;
  - Review whether LSEs used modern modeling frameworks;
  - Review if the IRPs capture an adequate set of assumptions;
  - Review whether each LSE took a capacity expansion or a "by hand" portfolio scenario approach;
  - Review and summarize the portfolio results for each LSE;
  - Perform independent validations of portfolio results using simplified modeling approaches; by mining output data such as capacity factors, market prices, and emissions factors;
  - Verify the reasonableness of the portfolio results;
  - Identify issues and shortcomings related to the development of the LSE scenarios and portfolios;
  - Identify and recommend alternative portfolios and scenarios;
  - Work with the LSEs to implement study runs of the proposed alternative scenarios and receive results, compare the results with the IRPS in the areas of cost, reliability, and environmental performance;
  - Recommend improvements to the IRPs and adoption of best practices;
  - Review methods for capturing risks;
  - Review the various assumptions used in the IRP demand forecasts including retail rates, utility demand management program offerings, electric vehicle adoption forecasts, electrification assumptions, climate related demand drivers, and energy service demand assumptions; and
  - Review the impacts of customer supply alternatives include din the IRPs such as solar photovoltaics ("PV") and PV plus storage.

Our Process

Data Gathering → **Ascend Develops Portfolios to Define Least Cost and Energy Rules** → **LSE's develop their own paths to 80% and 100% reduction by 2050 and run both cases** → **Results**

Data Gathering

- Review primary documents
- Data request
- Interviews

Ascend Develops Portfolios to Define Least Cost and Energy Rules

- Used IRP portfolios as starting point
- Added additional DSM, renewables and storage
- In out years, existing thermal units converted to burn hydrogen to provide "clean firm" capacity. (More on this later)
- Extended load through 2050, adding additional electrification load
- Additional "Ascend Assumptions" assumptions around power and gas prices.

LSE's develop their own paths to 80% and 100% reduction by 2050 and run both cases

- Used IRP portfolios as starting point
- Added additional DSM, renewables and storage
- Extended load through 2050, adding additional electrification load
- Did not model past 2050

Results

- Energy content
- Emissions
- Costs
- ✗ Reliability
- ✗ Other costs and benefits (e.g. jobs, air quality, etc.)

Not included in scope

Proposed Energy Rules

Section	Requirement
R14-2-2704 (B, 1)	By January 1 2030, a Load-Serving Entities resource portfolio shall include a Demand-Side Resource Capacity equal to at least **35% of the Load-Serving Entities 2020 peak demand**;
R14-2-2704 (B, 2, b)	Utilities must average at least **1.3% annual Energy Efficiency measured by megawatt-hour savings over the three-year planning period** without carrying over energy savings credits from programs implemented before January 1, 2021
R14-2-2704 (B, 3)	By December 31 2035, the installation of **Energy Storage Systems** with an aggregate capacity equal to **at least 5% of the Electric Utility's 2020 peak demand**, of which at least **40% shall be derived from Customer-owned or Customer-leased Distributed Storage**;
R14-2-2704 (B, 4)	Original: A **100% reduction in Carbon Emissions below its Baseline Carbon Emissions Level by 2050** with the following corresponding interim standards: (2032 = 50% below, 2040 = 75% below) Updated: A **100% reduction in Carbon Emissions below its Baseline Carbon Emissions Level by 2070** with the following corresponding interim standards: (2032 = 50% below, 2040 = 65% below, 2050 = 80% below, 2060 = 95% below) **- Modeled both original and updated through 2050.**
R14-2-2704 (E)	An Electric Utility's Baseline Carbon Emissions Level shall be the average annual metric tons of Carbon Emissions from all Generating Units used to meet the Electric Utility's retail kwh sales. during the consecutive three-calendar-year period of 2016 to 2018.

Approach to building low carbon portfolios

Ascend Analytics
Better models. Better decisions.

Reducing power system emissions, a simple formula?

Manage load growth through efficiency and more control

+

New clean energy resources

+

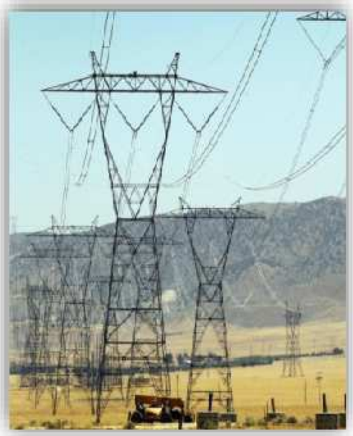
Transmission to move energy around long-distances

+

Technologies to integrate and store electricity

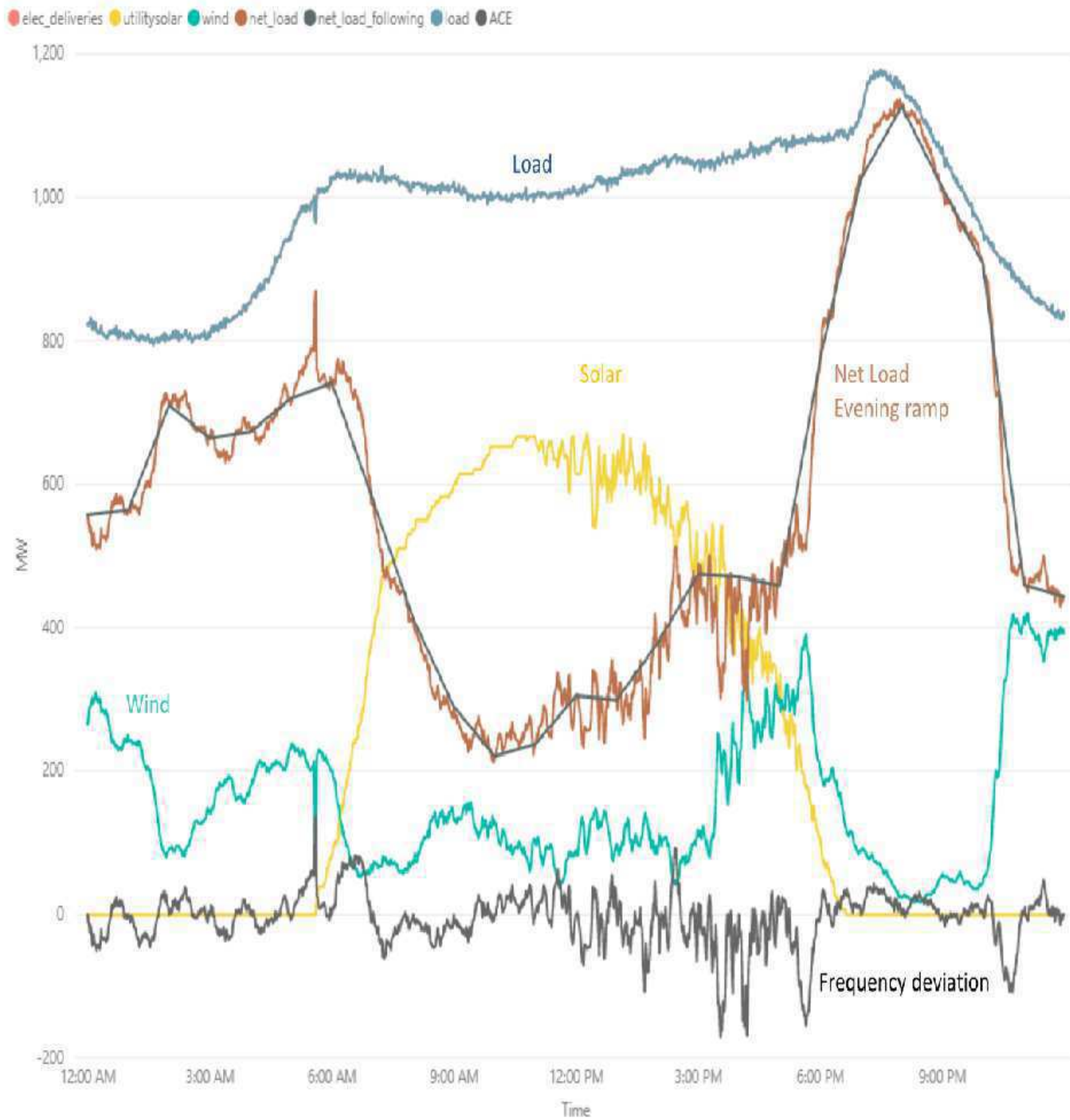
+

Conversion or retirement of legacy emitting resources



The Renewable Integration Challenge at Hourly and Sub-hourly Time Scales

A Southwest Power System in May 2025

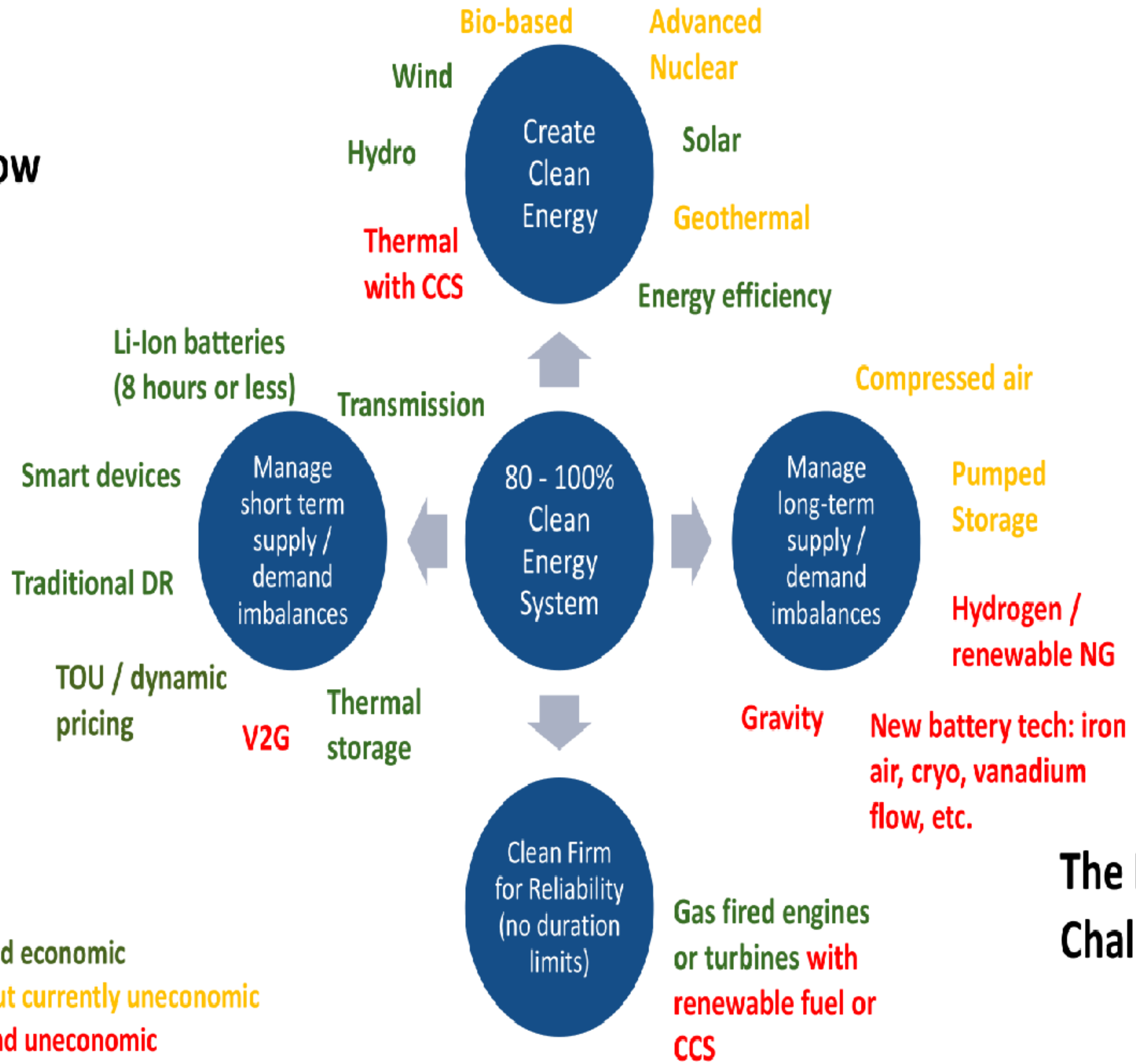


Flexible Capacity Must Address Variability in Load and Power Production Across Timescales

Timescale	**Seconds to Minutes** "Regulation"	**15 Mins – 1 Hour** "INC/DEC"	**1 - 8 Hours** "Load Following"	**8 hours -> Seasonal** "Critical Reliability and Decarbonization"
Requirement	Manage minutely variations between gen and net load.	Manage the difference between and actual loads and generation within the hour.	Manage the duck curve evening net load ramp. Reduce solar curtailment.	Decarbonize night and winter months. Save seasonal overgeneration for summer. Ride through wind/solar droughts.
Technologies and Strategies	1 hour battery, flexible thermal.	2-hour battery, flexible thermal, flexible demand, EIM.	4- 8-hour battery, flexible thermal, transmission, EIM, flexible demand.	100 hour+ storage, "clean firm" resources, transmission, nuclear, flexible demand.

Core Components of High Clean Energy Systems

Ready to go now



The Innovation Challenge Ahead

Green indicates proven and economic
Yellow indicates proven but currently uneconomic
Red indicates unproven and uneconomic

Results and Interpretations

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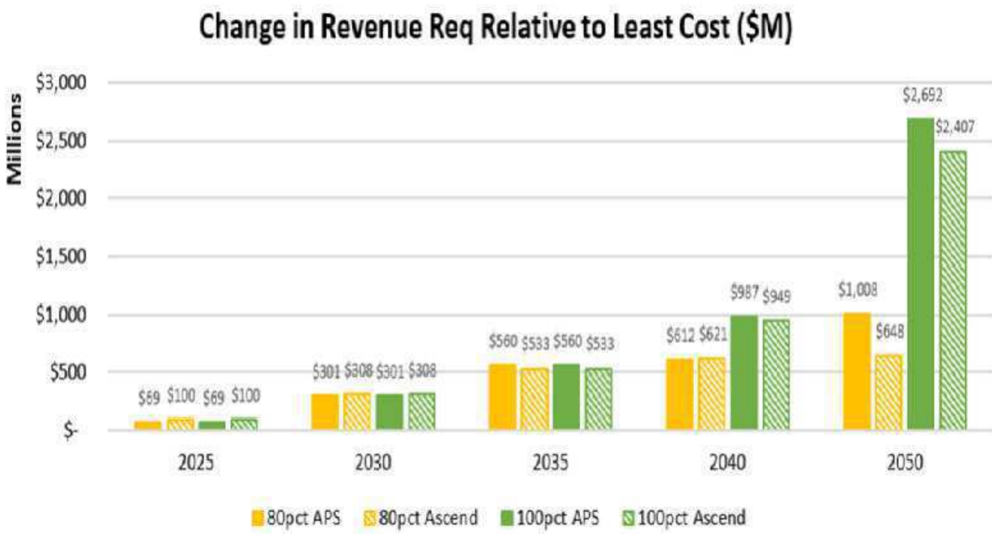
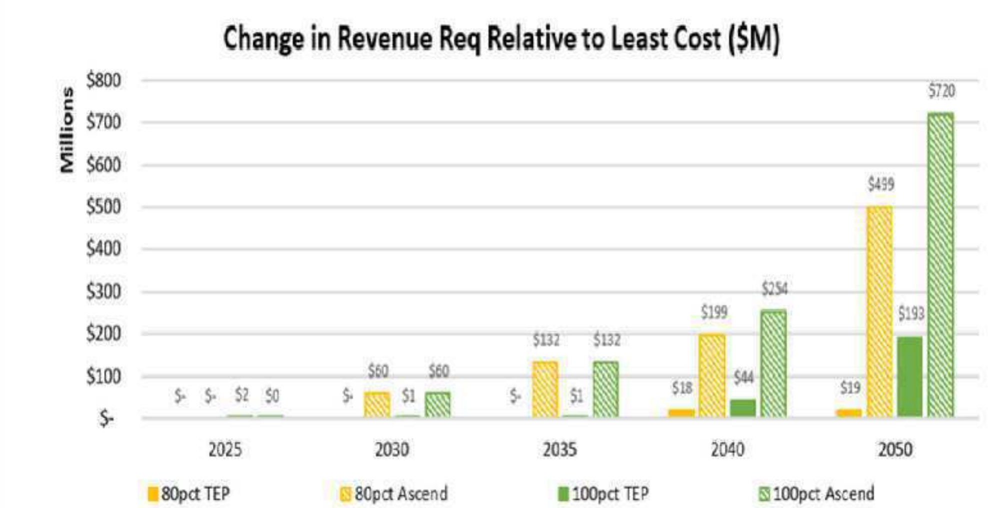
Summary of Results – Change in Revenue Requirements Relative to Least-Cost

APS

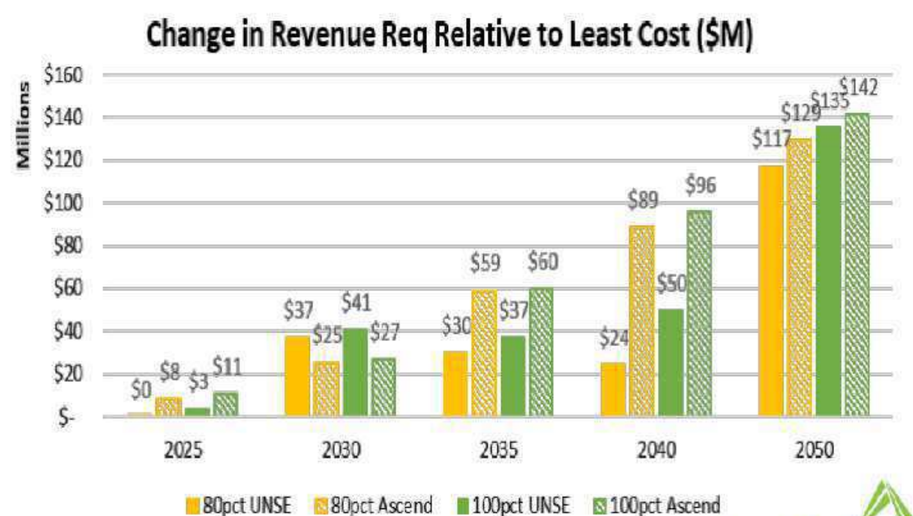


In Millions $		2035 (Nominal)	2050 (Nominal)	2035 ($2021)	2050 ($2021)
APS	80%	533 – 560	648 – 1,008	377 – 396	317 – 493
	100%	533 – 560	2,407 – 2,692	377 – 396	1,176 – 1,315
TEP	80%	0 – 132	19 – 499	0 – 93	9 – 244
	100%	1 – 132	193 – 720	1 – 93	94 – 352
UNSE	80%	30 – 59	117 – 129	21 – 42	57 – 63
	100%	37 – 60	135 – 142	26 – 42	66 – 69

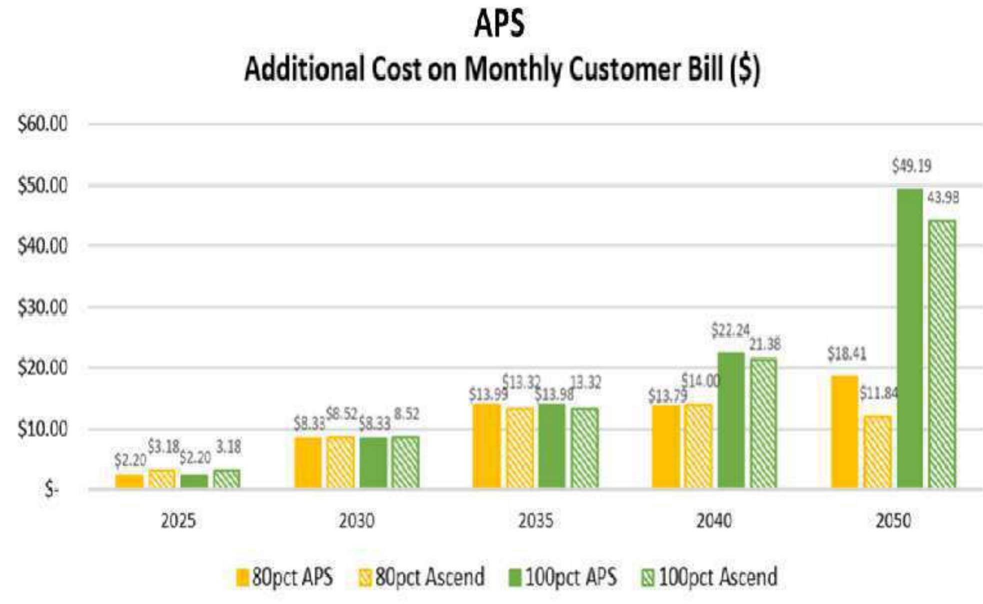
TEP



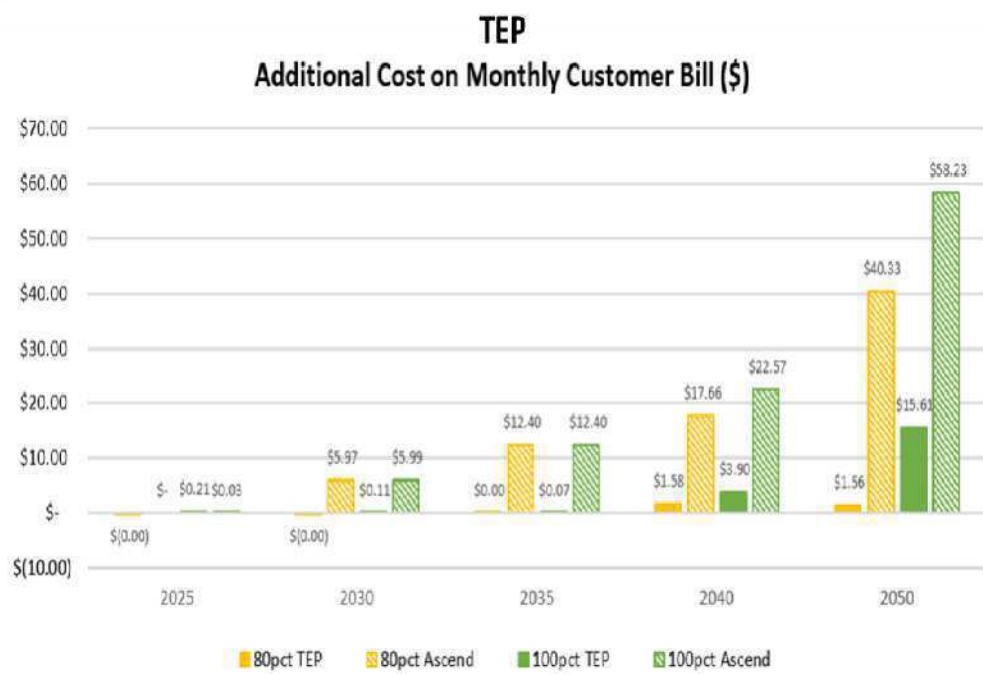
UNSE

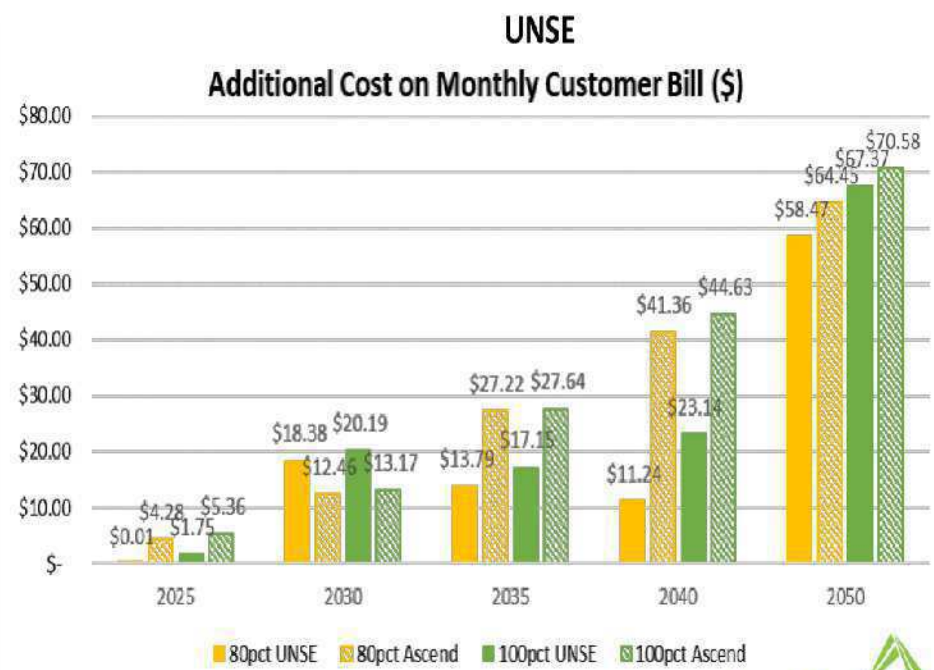


Summary of Results – Bill Impacts



In dollars/month		2035 (Nominal)	2050 (Nominal)	2035 ($2021)	2050 ($2021)
APS	80%	13 – 14	12 – 18	9 – 10	6 – 9
	100%	13 – 14	44 – 49	9 – 10	22 – 24
TEP	80%	0 – 12	2 – 40	0 – 8	1 – 20
	100%	0 – 12	16 – 58	0 – 8	8 – 28
UNSE	80%	14 – 27	58 – 64	10 – 19	28 – 31
	100%	17 – 28	67 – 71	12 – 20	33 – 35





Energy Rules Key Takeaways

- In the near and mid term, the results show **low to moderate cost increases in revenue requirements, rates, and bills in both 80% and 100% pathways.**
- **The most significant cost increases would occur between the 2040- and 2050-time frame** when the utilities achieve between 80 to 100% clean energy. This is due to the need to convert natural gas fired power plants to burn expensive green hydrogen and add longer duration storage (8 to 100 hours) required for capacity and reliability.
- The wider uncertainty band in the TEP results is indicative of **differing assumptions on the load carrying capability of renewables and storage.** Ascend predicts a faster decline in the ability of solar, wind, and 4-hour storage to provide system reliability than TEP, therefore the Ascend assumptions for TEP's portfolios includes additional capacity and additional cost. TEP also has more aggressive assumptions for decline in clean energy technology costs than what is published in the NREL ATB database.
- **Achieving at least 80% clean energy can be reliable and cost-effective with today's technology costs and capabilities.** Cost-effectively achieving higher than 80% clean energy while maintaining reliability requires innovation in clean energy technologies, such as green hydrogen, long-duration storage, advanced nuclear, or something else we haven't thought of yet.

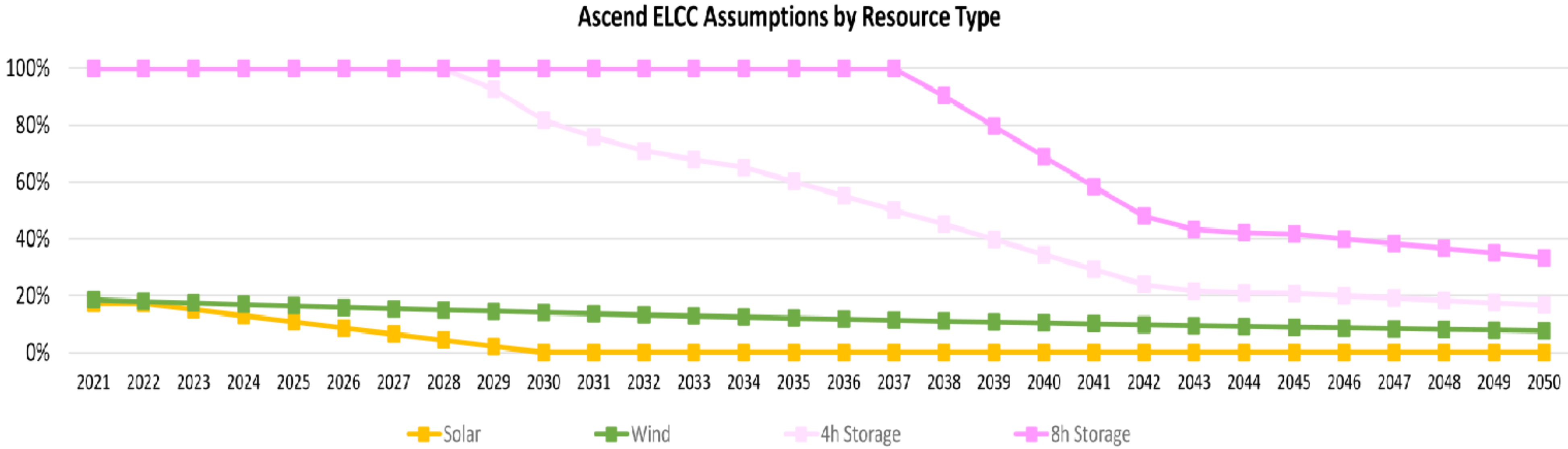
Understanding How Assumptions Change Results

Assumption	What would cause the Clean Portfolio to cost less than expected relative to Gas Portfolio?	What would cause the Clean Portfolio to cost more than expected relative to Gas Portfolio?
Effective load carrying capability (ELCC)	ELCC of wind, solar, and batteries are more than we expect, potentially as a function of portfolio effects and geographic diversity.	ELCC of wind, solar, and batteries are less than we expect, potentially as a function of strong correlation in weather regimes on renewable output.
Technology types and costs	If innovation makes storage dramatically more cost-effective, then we expect costs of decarbonization would decrease.	If future technology costs do not decline as we expect, then costs to decarbonize would be higher than shown here.
Commodity Cost	Increasing gas prices, driven by global demand and limitations on supply.	Return to low prices of gas. Robust gas production supply response. Few limits on fracking leasing.
Climate change	Climate impacts are more moderate than we expect, meaning less need to build peaking capacity for heat storms.	Climate impacts are worse than we expect, therefore additional capacity is needed to maintain reliability during more frequent and longer heat storms and extreme weather patterns.
Market structure	If LSEs join a regional RTO, the cost of decarbonization may decrease due to better coordination of resources across the West.	Regional providers underpredict resource needs and overpredict their ability to import, resulting in regionwide shortages and inability to purchase power.
Transmission	Federal spending and permitting reforms support additional transmission that unlocks more low-cost renewable energy. Higher adoption and targeted deployment of distribution-sited storage and distributed energy resources reduces the need for transmission spending.	No federal spending or permitting reform. Low adoption/sub-optimal deployment of distributed energy resources.

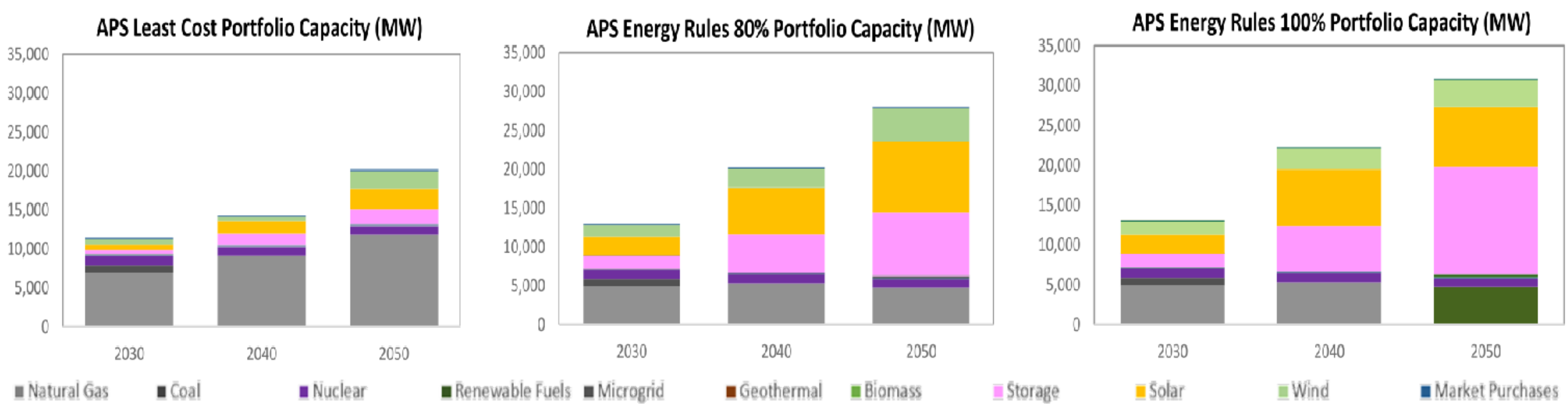
Understanding ELCC as a Key Driver

Ascend Analytics

- **Key concept:** the effective load carrying capability (ELCC) of renewables and duration limited storage declines as penetration increases. ELCC = ability of a resource to be available when needed to meet load, especially during the peak hours.



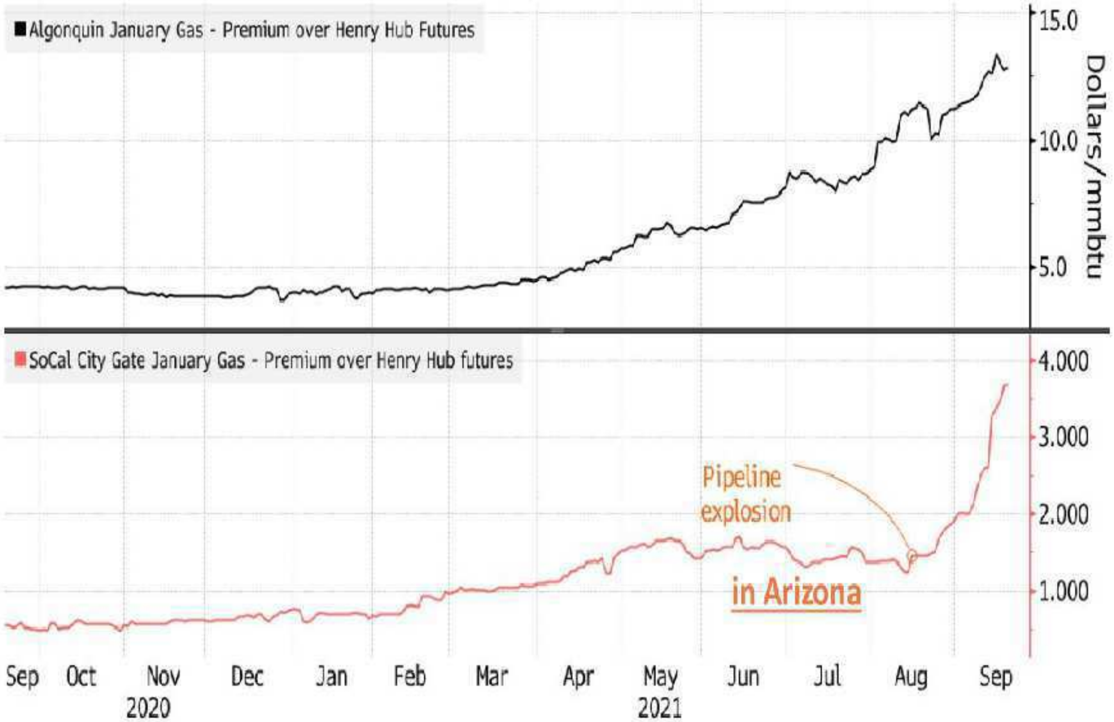
- Lower expectation of renewable ELCC means more firm capacity resources will be needed, which drives up costs



Key Uncertainty and Risk: Natural Gas Price Forecast

Winter Risk

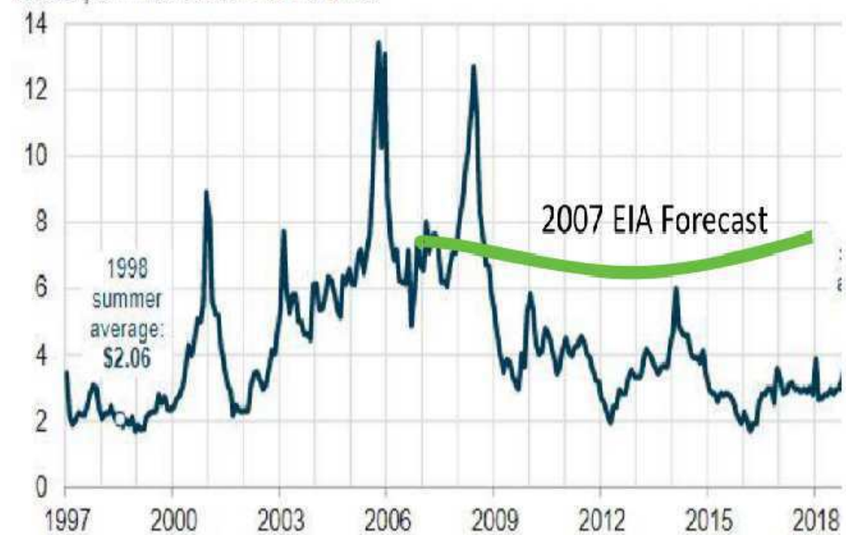
New England and California gas trading at a rising premium over U.S. benchmark



Source: Bloomberg

Monthly Henry Hub natural gas spot prices (1997-2019)

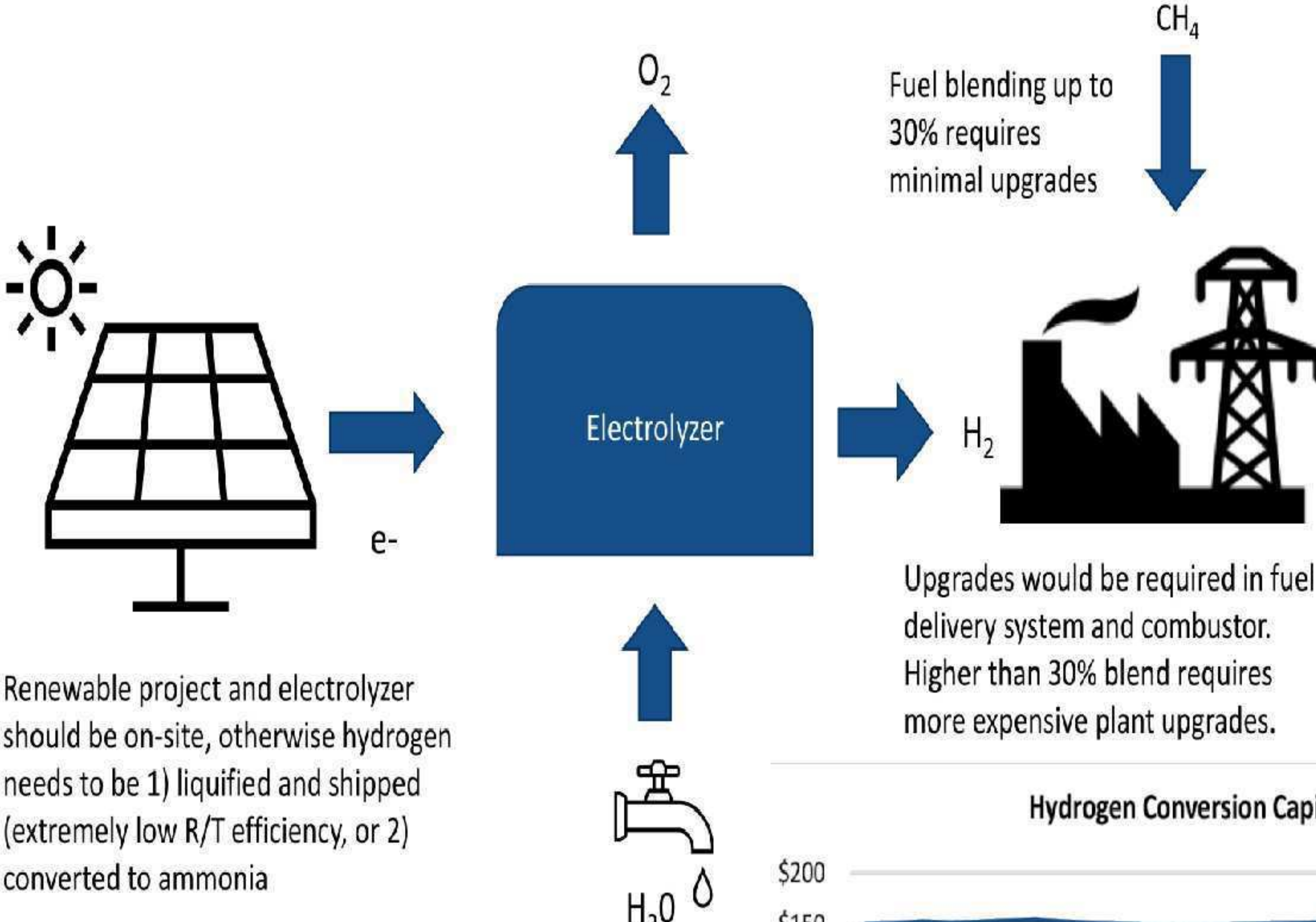
dollars per million British thermal units



Energy crisis forces EU ministers to face up to reliance on natural gas

Analysis: As governments shield consumers against soaring prices, Russia and renewables are coming under scrutiny

Understanding key drivers -> Conversion of existing gas to burn green hydrogen



Fuel blending up to 30% requires minimal upgrades

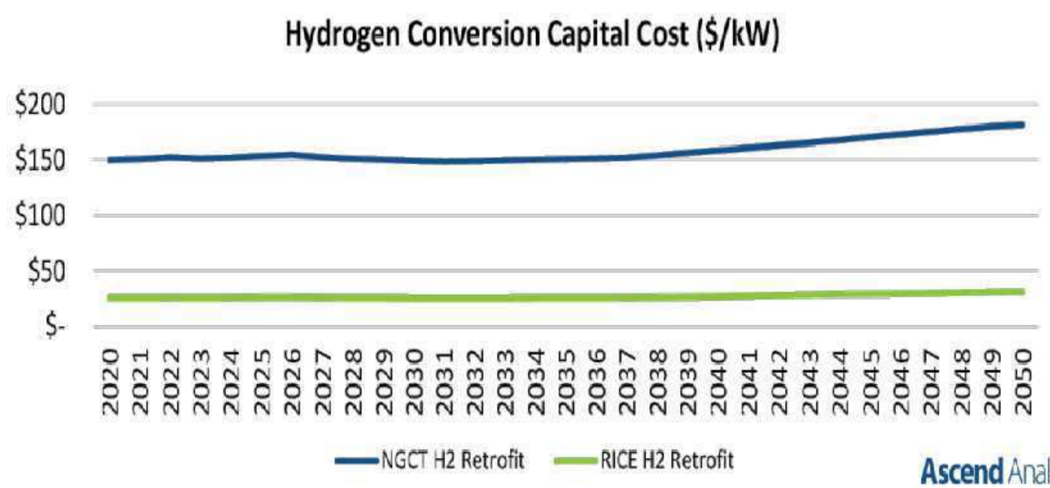
Upgrades would be required in fuel delivery system and combustor. Higher than 30% blend requires more expensive plant upgrades.

Renewable project and electrolyzer should be on-site, otherwise hydrogen needs to be 1) liquified and shipped (extremely low R/T efficiency, or 2) converted to ammonia

Hydrogen is 3X less energy dense by volume than methane. Therefore 30% green hydrogen is equivalent to 10% decarbonization

Green hydrogen is about 6X more expensive than natural gas today, and assumed to be 2x more expensive by 2050

Major challenges remain in increasing electrolyze efficiency energy loss and delivering fuel to power plants.



Uses and Limitations of Long-Range Cost Modeling

- 2050 is a long way away…but 2030 is quite close
  - We have little ability to predict what technologies will be available and what they will cost
  - Imagine predicting the iPhone <u>in the 1980s</u>
- Models provide a useful lens into **near-term decisions** and **raise awareness** of long-term challenges to start working on
  - IRPs all show general alignment with meeting Energy Rules in the near term with existing and proven technologies
- Modeling exercise was necessarily limited due to time constraints and modeling limitations:
  - Only tested a few scenarios
  - Did not use optimized capacity expansion
  - No loss of load analysis to test for reliability
  - Deterministic, weather normalized inputs, no sub-hourly value

Recommendations and Next Steps

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Better models. Better decisions.

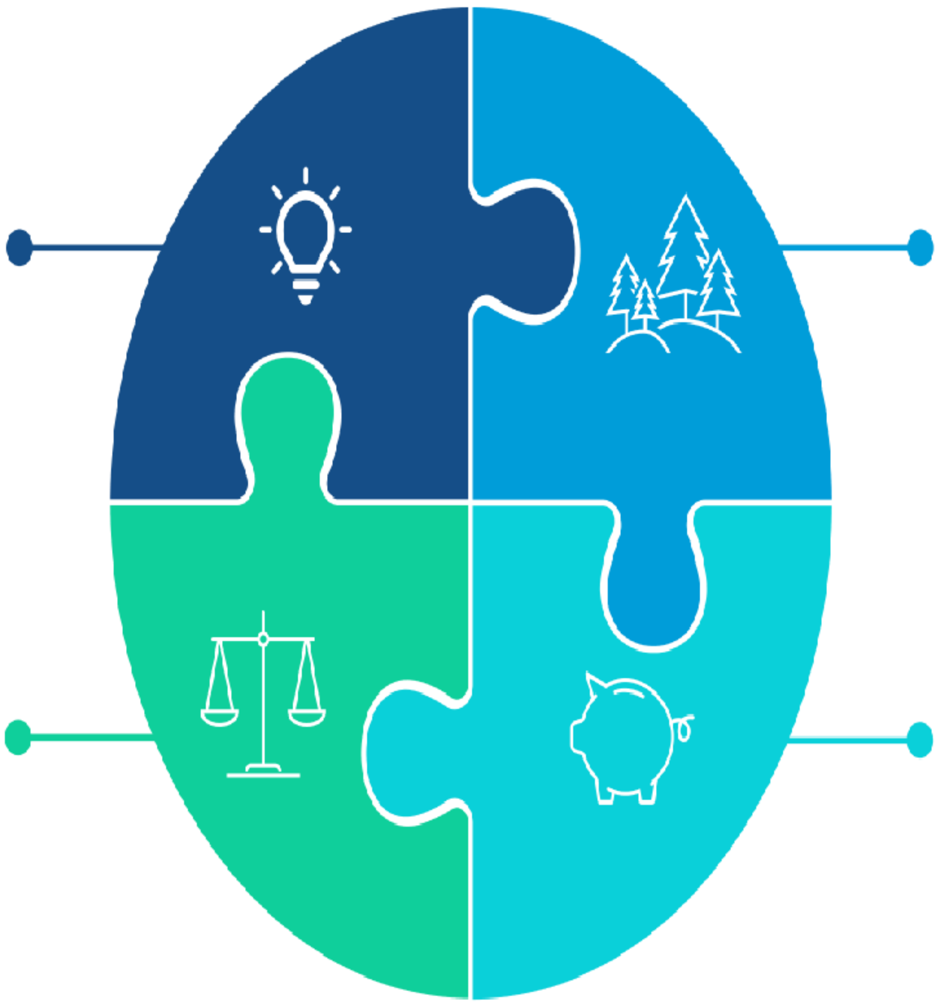
Ascend's Four Principles of Modern Resource Planning

Reliability and Resiliency

Keep the lights on and recover quickly in emergencies

Sustainability

Rapidly reduce GHG and air pollution from electricity supply



Equity

Remediate impacts of fossil fuel-based pollution and accrue clean energy benefits to historically marginalized communities

Affordability

Electricity must be universal and affordable to support enterprise, economic wellbeing, and beneficial electrification

Recommendations on Modeling

Modeling is a "mosaic." Add HD PCM capabilities.

- No one model can provide all the insights. Multiple models provide multiple perspectives.
- "HD" PCMs provide additional insight using modern computing technology to drill deeper with weather simulation, sub-hourly, and imperfect foresight

Add capacity expansion optimization to the toolkit

- Start as unconstrained as possible
- All options must be on the table (both demand and supply side)
- Use discrete scenarios to test various hypotheses

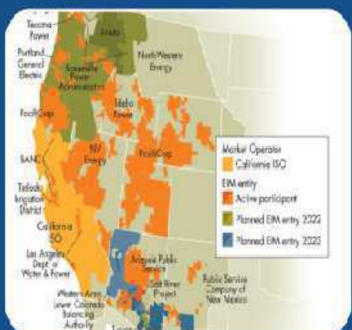
Add more robust tools for reliability and resiliency planning

- Simulate weather's impact on load, renewable output, outages, and battery state of charge
- Add climate impacts

Recommendations on Modeling

Include other sectors

- Utilities must plan for vehicle and building electrification as part of an all-sector decarbonization approach
- Measures taken outside of electricity sector may be more cost-effective!



Integrate planning with EIM/RTO participation

- Expect greater integration of markets across the WECC
- Sub-hourly price modeling reveals value of flexible resources

Quantify other costs and benefits

- Air quality, jobs, tax revenues, water consumption, climate leadership, etc.

Increasing Weather Risks (impacts on load and supply)

Coincident droughts, heat waves, and fires across the west are challenging the region's ability to rely on imports and hydro for meeting peak demand.

August 2021

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U.S.

Severe Drought Could Threaten Power Supply in West for Years to Come

Water elevation at the Hoover Dam is at its lowest since Lake Mead was first filled

CNN US Crime + Justice Energy + Environment Extreme Weather Space + Science • LIVE TV Edition

California hydropower plant forced to shut down as water levels fall at Lake Oroville

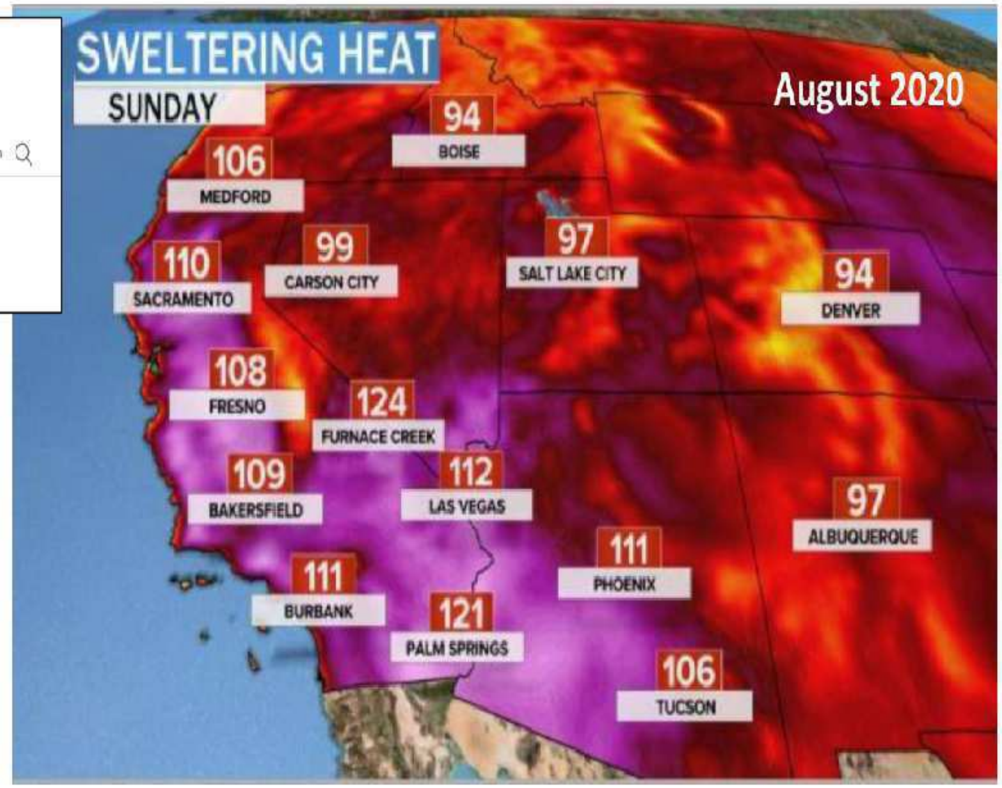
August 2021

By Alexandra Meeks and Dakin Andone, CNN

Updated 10:33 AM ET, Fri August 6, 2021

More from CNN

'I hope I'm wrong': GOP lawmaker explains mixed feelings over...

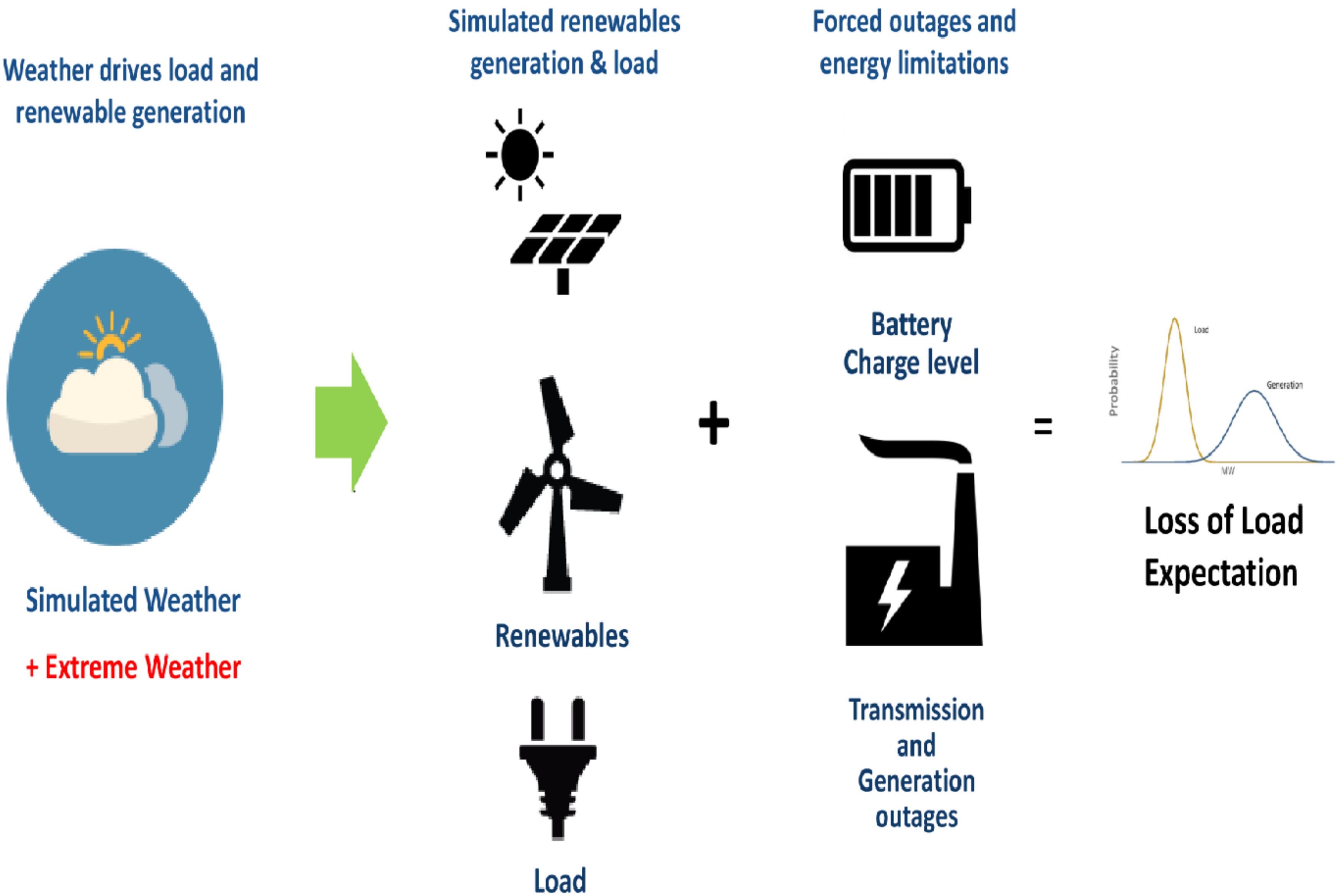


Los Angeles Times

July 2021

How an Oregon wildfire almost derailed California's power grid

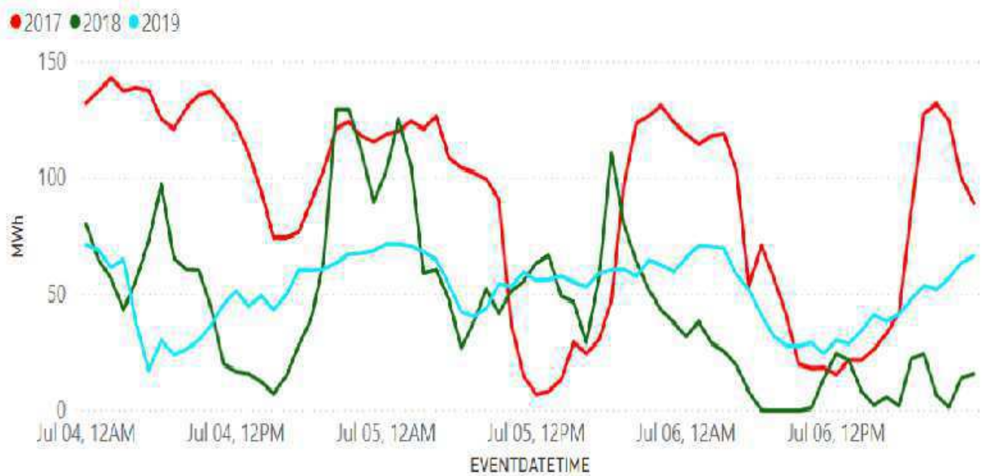
Understanding Modern Reliability Planning



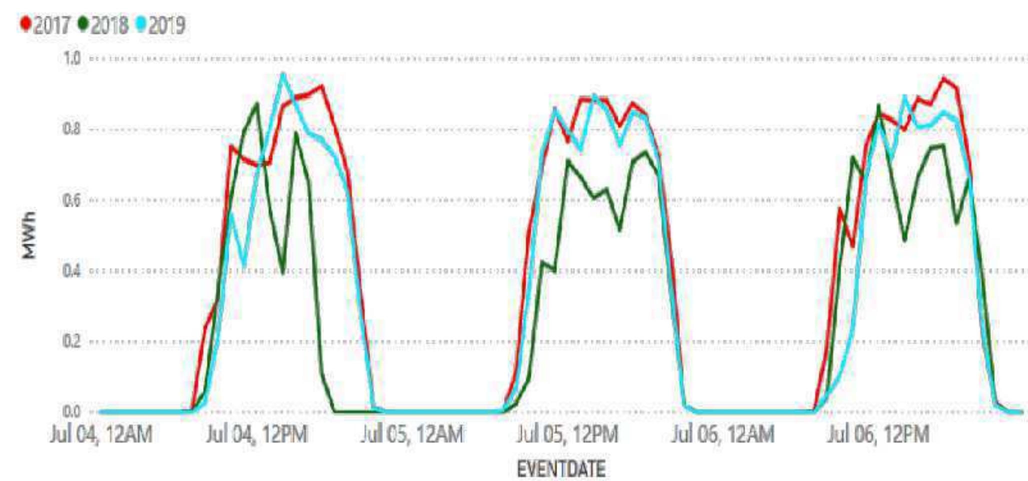
Why Simulate Weather -> Renewable Generation?

- Real generation profiles vary:
  - From hour-to-hour
  - From day-to-day
  - From year-to-year
- **Average generation profiles miss these variations**, and can misrepresent system reliability under actual operation conditions
- **Wind is more variable than solar,** making it more of a challenge to rely on it to provide consistent energy on demand.

Example Historical Wind Generation

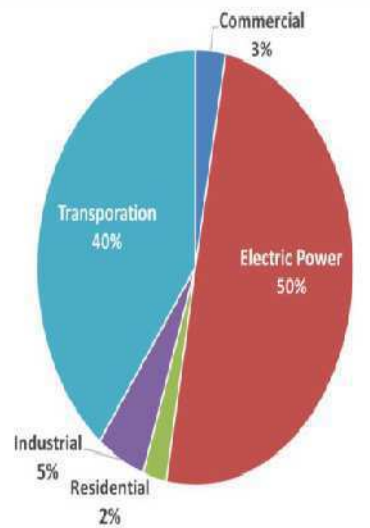


Example Historical Solar Generation



Include all Sectors of the Economy

Arizona GHG Emissions By Sector



We live in a digital world, are you still making decisions with analog technology?

Your model is a lens into the future. How far can you see?
How clear is the image?

Does this lens suffer from "model limited choice"?

Selecting a sub-optimal resource mix because of limited information.

Result: *Legacy models lead to legacy decisions.*

Time and again deterministic hourly production cost models select CCs and CTs. Models that simulate a broader set of outcome and use a finer time-step (5 minutes) and imperfect foresight select batteries.

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Details for Each LSE

Summary of APS/TEP Price and Technology Cost Forecast Implications

Implied heat rates (power price / gas price): indicator for the profitability of gas generation

- TEP forecast has high implied heat rates
  - Will lead to a *higher valuation for NG resources* than the Ascend or APS views, with the entire generation fleet competitive relative to Palo Verde prices
- APS forecast has very low spring and summer heat rates
  - Will lead to *depressed valuation for gas resources*

Power prices: indicator for economics of renewable, nuclear, and coal generation

- TEP forecast has much higher power prices than Ascend or APS
  - Will lead to a *higher valuation for renewables*, with 'ducky' price shapes only slightly tempering the value
- APS forecast has much lower power prices than Ascend or TEP, particularly in spring and summer
  - Will *underestimate the costs and revenues of market interactions* for all resources

Technology costs: indicator for future resource economics

- TEP and APS cost forecasts *are reasonable* relative to appropriate benchmarks, and account for expected future cost declines

Summary:

- TEP forecast likely overvalues the portfolio relative to market prices, which could lead to an overvaluation of thermal resources relative to storage
- APS forecast likely underestimates the cost of market purchases and the value of market sales, which could lead to an undervaluation of portfolio resources

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Must-Run Questions

Four Corners

- APS modeled the Four Corners coal power plant as a must-run resource in the IRP production cost models
- Ownership of Four Corners is split among five entities with an agreement for a minimum coal delivery per year that translates to an average generation of 60% to 65% around the clock
- It will take several years to develop a suitable replacement portfolio for the retiring Four Corners plant.
- APS should evaluate potential options for an earlier retirement.

Solana PPA

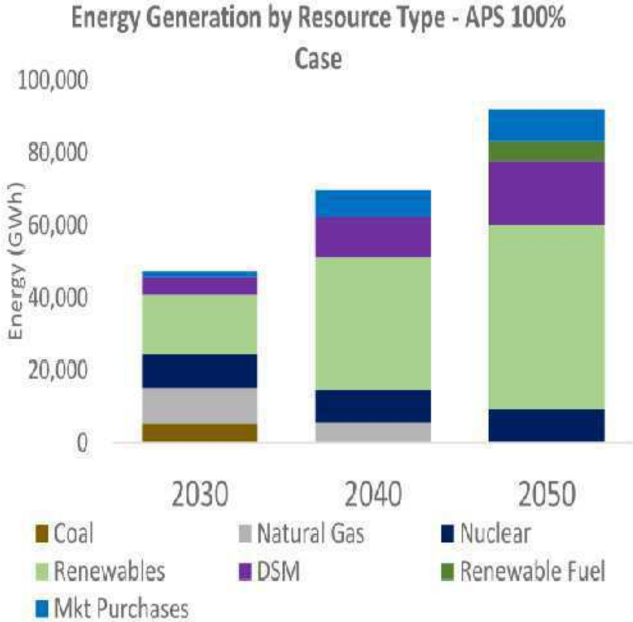
- Solana is a must take resource via contract terms like any other solar Power Purchase Agreement (PPA)
- The cost of Solana reflects the fact that it was a risky investment in new solar technology in 2008
- APS is contractually bound to the PPA for the duration of the contract
- Ascend agrees with APS in modeling Solana as a must take solar and storage project
- While Solana is significantly more expensive than power purchases today, this was not the case in 2008 when the procurement of Solana was approved by the ACC

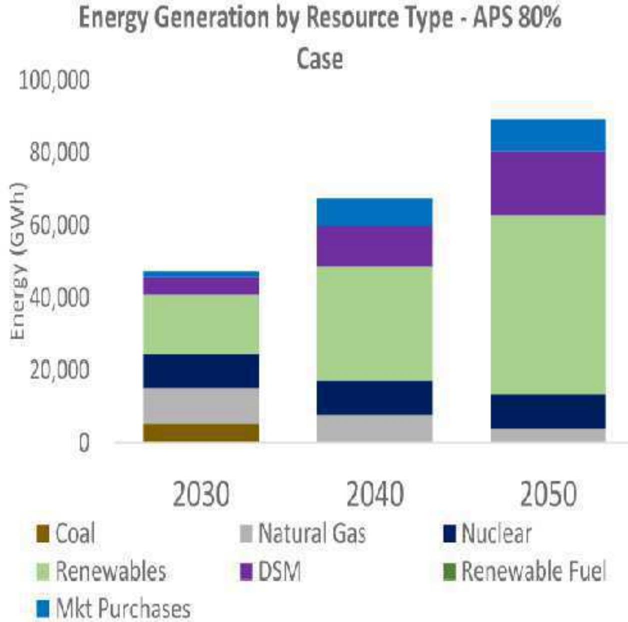
Energy Rules Portfolios Tested

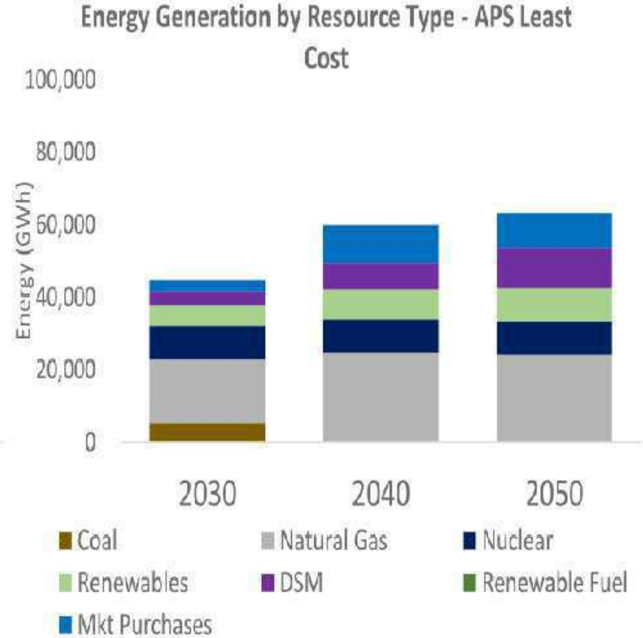
- Portfolios with the APS assumptions were identical with the Ascend assumptions

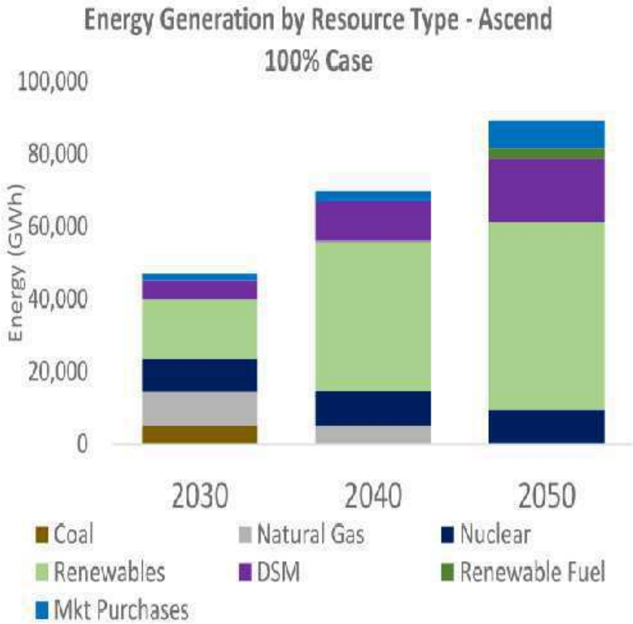
	Least Cost			Energy Rules 80%			Energy Rules 100%		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Natural Gas	6,923	9,093	11,807	4,933	5,295	4,730	4,933	5,295	-
Coal	970	-	-	970	-	-	970	-	-
Nuclear	1,146	1,146	1,146	1,146	1,146	1,146	1,146	1,146	1,146
Solar	717	1,549	2,645	2,417	6,024	9,120	2,417	7,074	7,570
Wind	647	600	2,250	1,597	2,400	4,300	1,597	2,600	3,300
Geothermal	-	-	-	-	-	250	-	-	250
Biomass	3	-	-	3	-	-	3	-	-
Storage (4 hours)	552	1,400	1,850	1,702	3,550	3,400	1,702	3,550	5,000
Storage (8 hours)	-	-	-	-	1,250	1,250	-	1,250	5,000
Storage (12 hours)	-	-	-	-	200	3,500	-	1,000	3,500
Microgrid	263	313	313	88	163	163	88	163	163
Market Purchases	160	160	160	160	160	160	160	160	160
Renewable Fuels	-	-	-	-	-	-	-	-	4,706

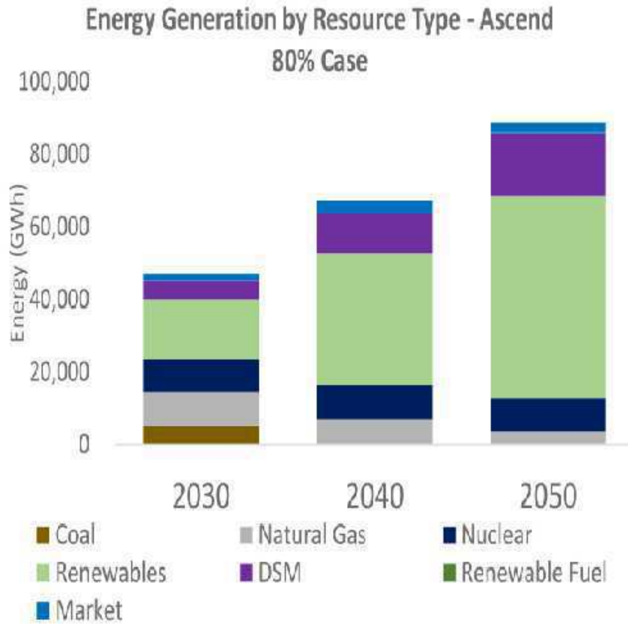
Energy Mix – Energy Rules Portfolios

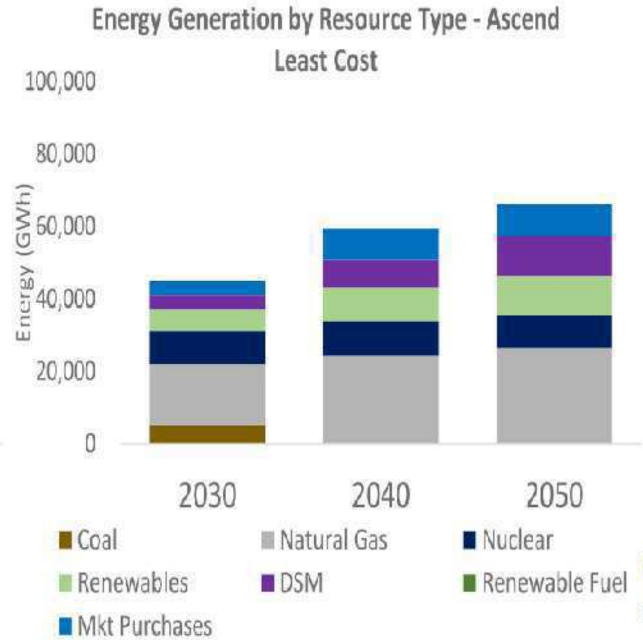




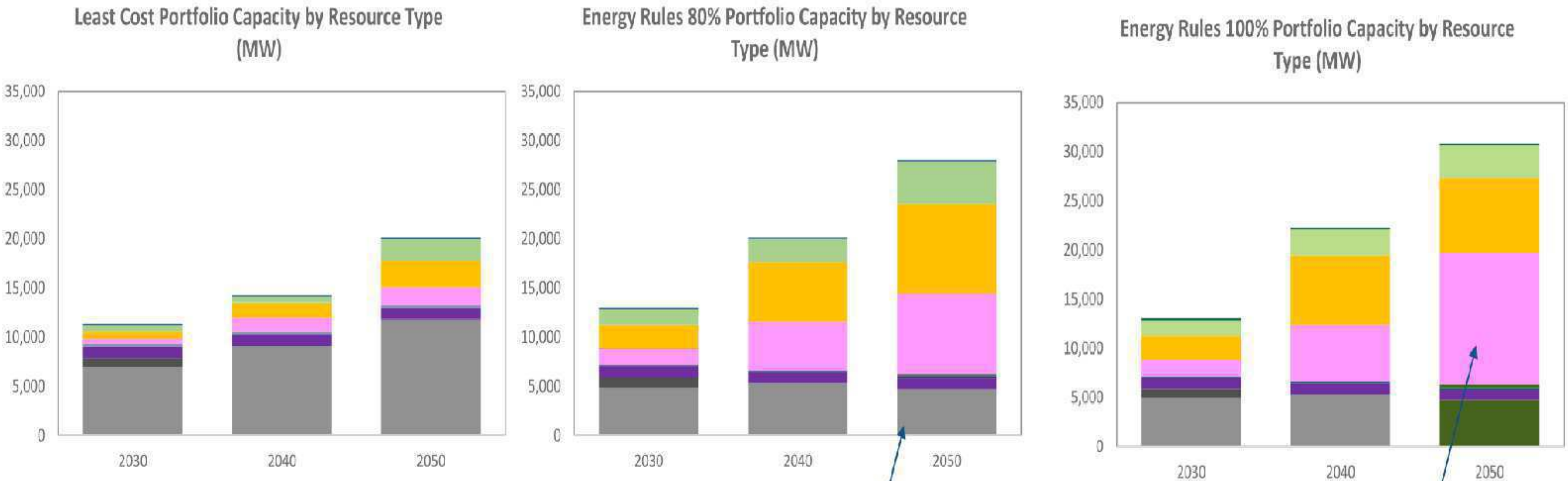








Capacity Mix – Energy Rules Portfolios

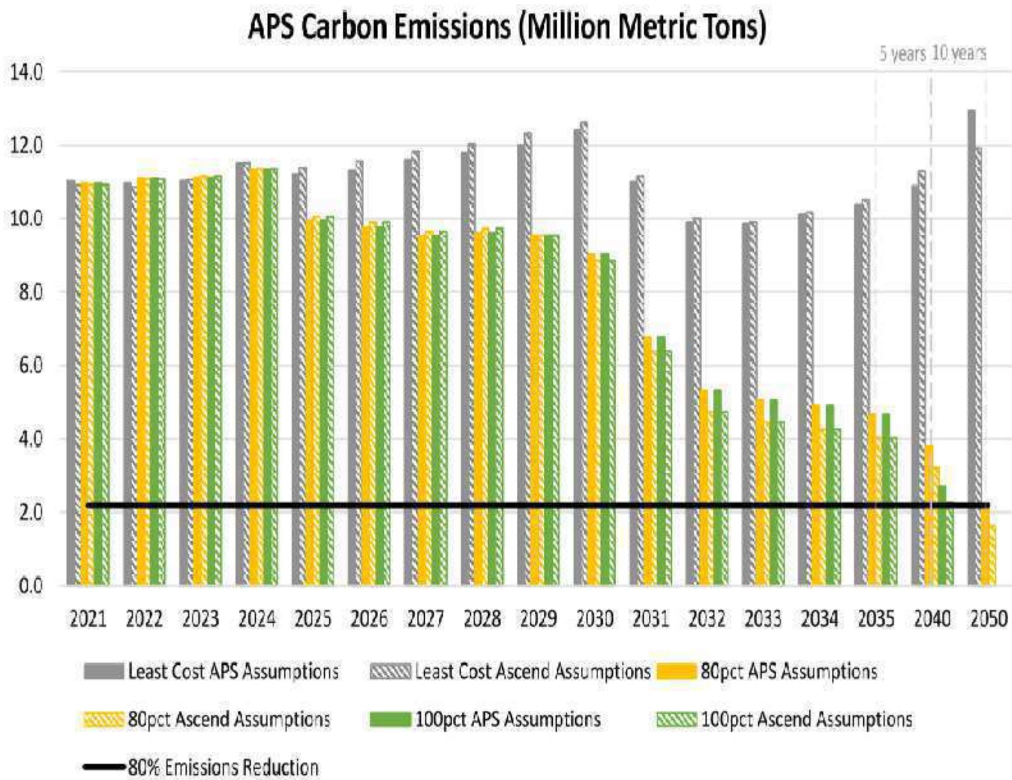


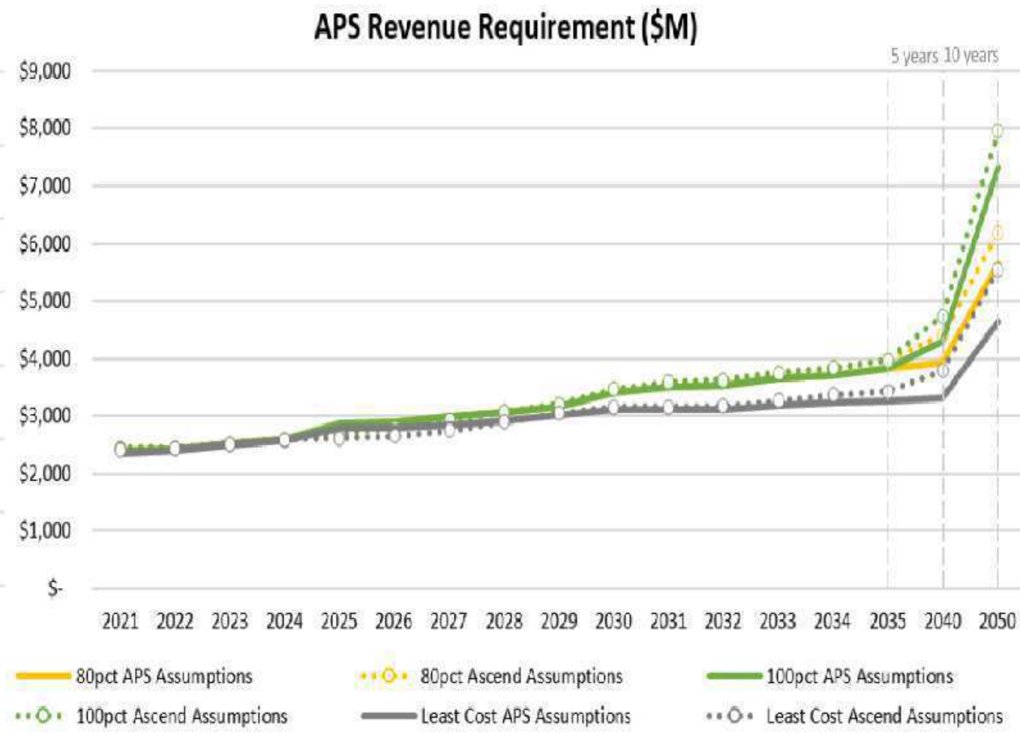
"Least-cost" relies primarily on gas, which has more firm capacity, does not rely much on renewables or storage

More Reliance on Storage and Renewable Fuels

No need for renewable fuels in 80% Case

Energy Rules Results





- Carbon targets for the Energy Rules portfolios are met in 2032, 2040, and 2050 in all cases
- The retirement of Four Corners in 2031 accounts for some of the carbon reduction between 2030 and 2040
- Revenue requirements rises significantly between 2040 and 2050 for the 100% case relative to the least cost case
- The 80% and 100% cases have the same path for the first 15 years and have similar costs and emissions

IRP Review

- APS worked with a group of stakeholders to develop a set of portfolios meant to achieve a range of clean energy and storage build out. All portfolios were meant to put APS on a path to 100% clean energy by 2050 with an interim target of 65% clean energy in 2030 and an end to coal-fired generation in 2031.
- The analysis of the three portfolios resulted in a short-term action plan for APS to move towards the clean energy commitments with a no-regrets approach that allows for flexibility as technology changes are evaluated in future IRPs
- Ascend reviewed APS's inputs and assumptions used in the IRP models and found them to be in line with Ascend's assumptions including power prices, natural gas prices, technology costs and capacity contributions from renewables and energy storage.
- Ascend made some suggestions for improvements to the next IRP
    - Use capacity expansion models to guide the development of portfolios
    - Perform sub-hourly modeling to capture the full benefits of flexible generation and energy storage, especially in the CAISO EIM
    - Run full stochastic models that simulate load and renewables as a function of weather
    - Include power prices in the sensitivity analysis
    - Evaluate the costs and benefits of earlier coal retirements
    - Perform resource adequacy modeling for future years with higher levels of renewables and batteries

TEP

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Portfolios Modeled for Energy Rules Analysis

Portfolios Designed Using TEP Assumptions

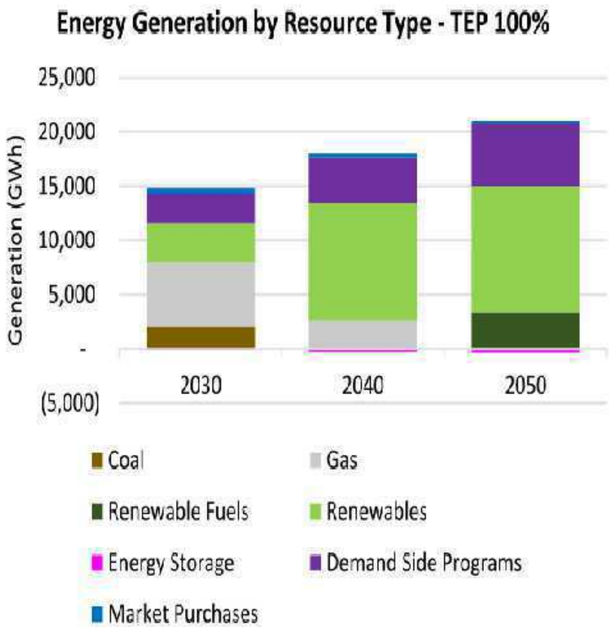
	TEP Least Cost			TEP Energy Rules 80%			TEP Energy Rules 100%		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Natural Gas	1,679	1,419	1,419	1,679	1,419	1,419	1,679	1,757	-
Coal	516	-	-	516	-	-	516	-	-
Nuclear	-	-	-	-	-	-	-	-	-
Solar	548	1,969	1,969	548	2,669	3,169	548	2,669	3,169
Wind	625	1,075	1,075	625	1,625	1,625	625	1,625	1,625
Geothermal	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-
Storage (4 hours)	595	1,445	1,445	595	1,445	1,445	595	1,445	1,445
Storage (8 hours)	-	-	-	-	550	800	-	500	800
Storage (12 hours)	-	-	-	-	-	-	-	-	-
Renewable Fuels	-	-	-	-	-	-	-	-	1,757

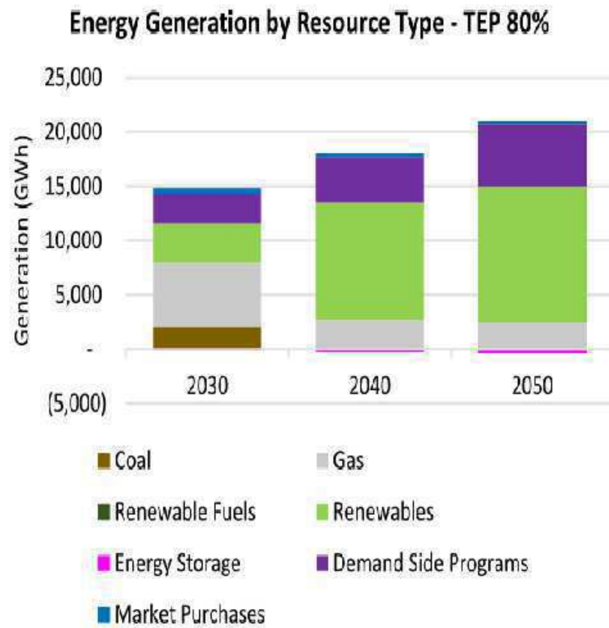
Portfolios Designed Using Ascend Assumptions

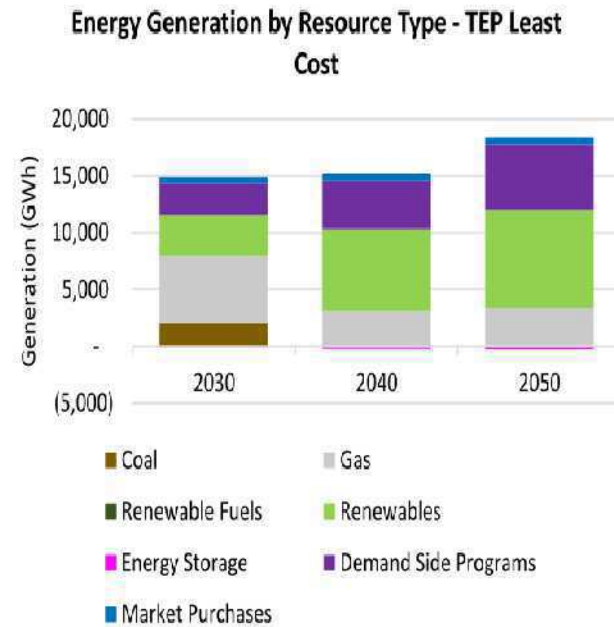
	Ascend Least Cost			Ascend Energy Rules 80%			Ascend Energy Rules 100%		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Natural Gas	2,329	3,048	2,725	1,679	1,623	1,972	1,679	1,373	-
Coal	516	-	-	516	-	-	516	-	-
Nuclear	-	-	-	-	-	-	-	-	-
Solar	548	2,169	1,919	548	1,169	3,169	458	2,169	4,169
Wind	625	875	1,419	625	1,875	2,875	625	1,875	2,875
Geothermal	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-
Storage (4 hours)	595	1,530	2,530	630	2,030	3,030	630	2,030	3,030
Storage (8 hours)	-	-	-	255	1,000	2,000	255	1,000	2,000
Storage (12 hours)	-	-	-	-	-	-	-	250	500
Renewable Fuels	-	-	-	-	-	-	-	-	1,725

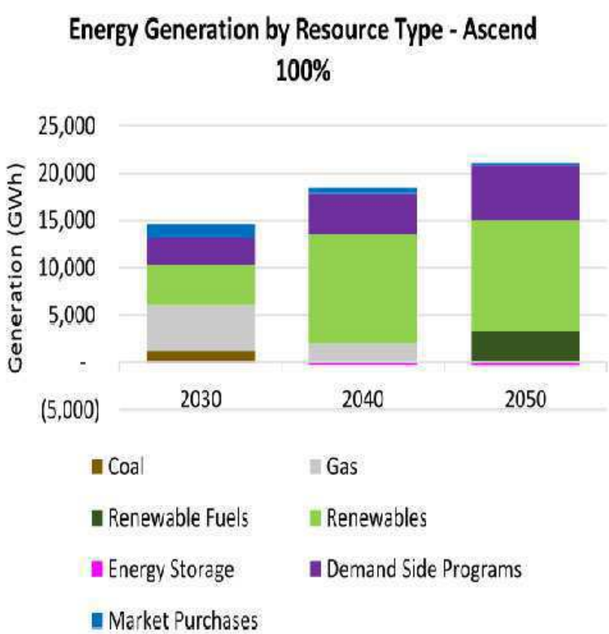
- The Ascend portfolios contain significantly more capacity than the TEP portfolios due to the differences in assumptions on reliability of renewables to deliver energy on an as needed basis.
- Both Ascend and TEP rely on renewable fuels to keep the portfolios adequate through 2050 in the 100% cases

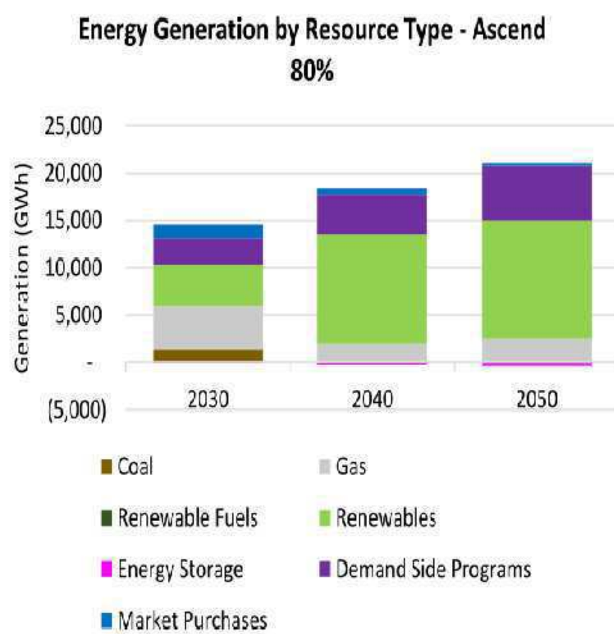
Energy Mix – Energy Rules Portfolios

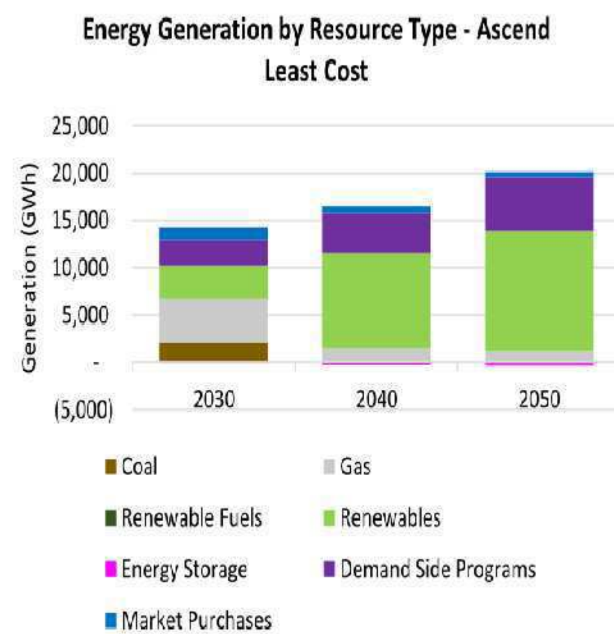




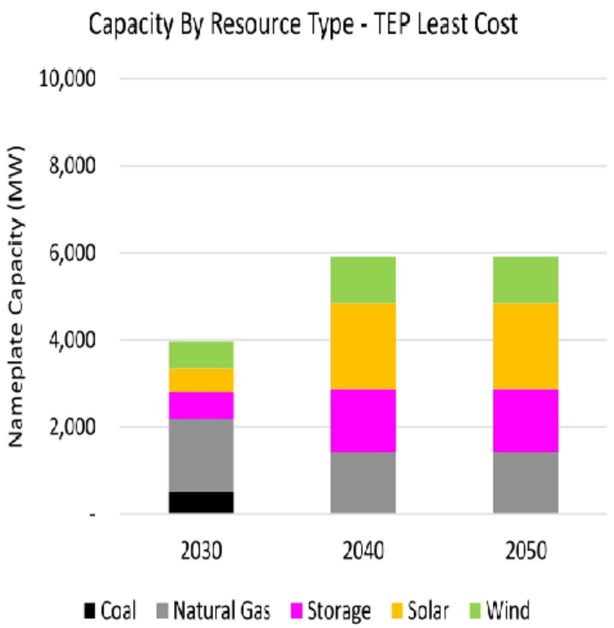


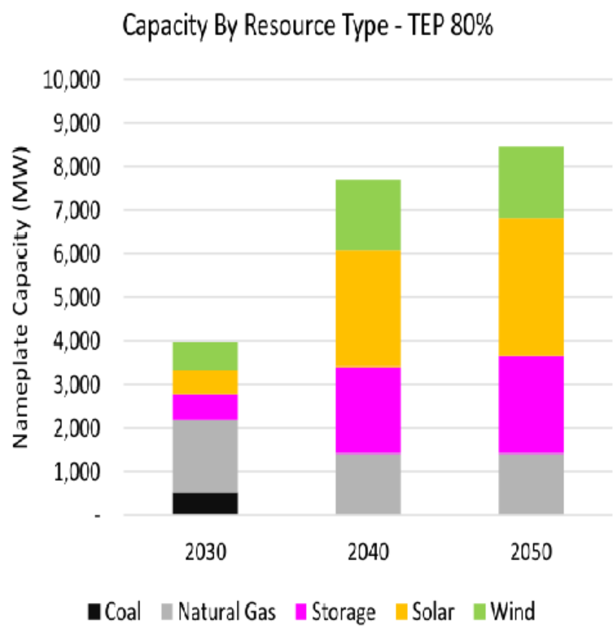


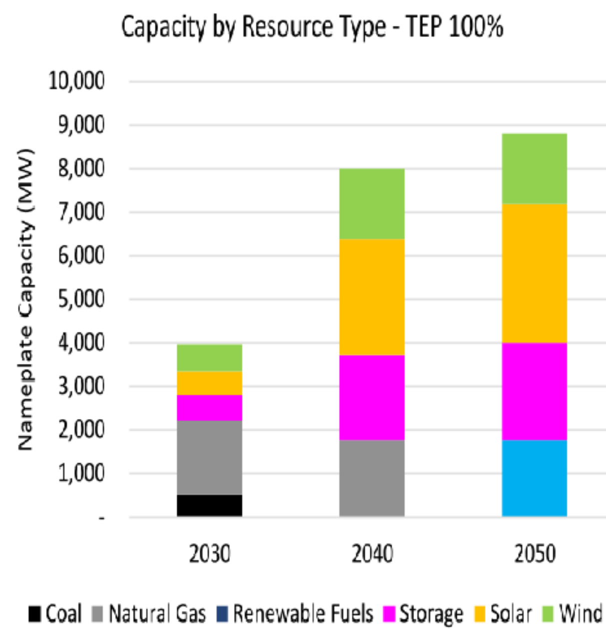


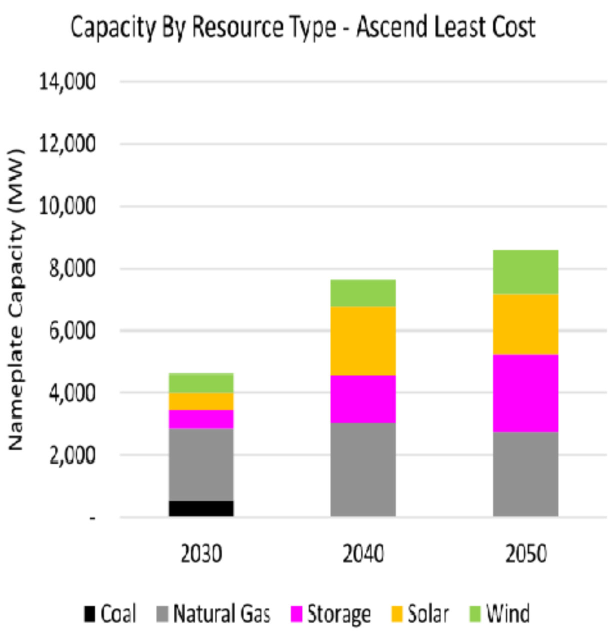


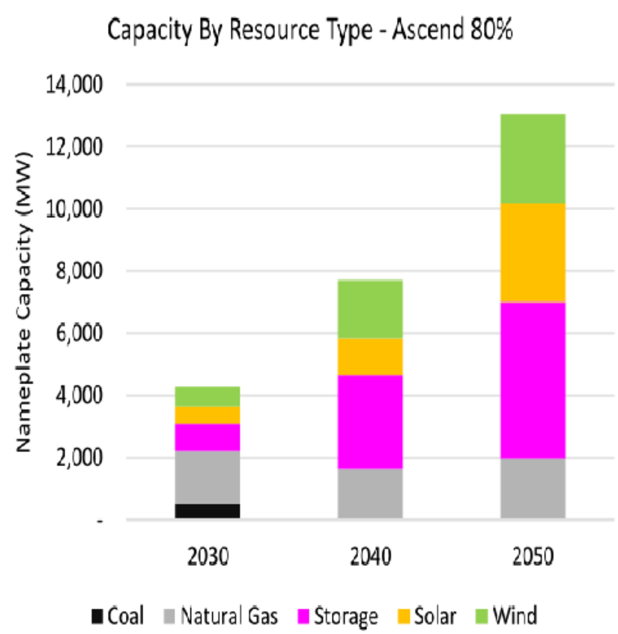
Capacity Mix – Energy Rules Portfolios

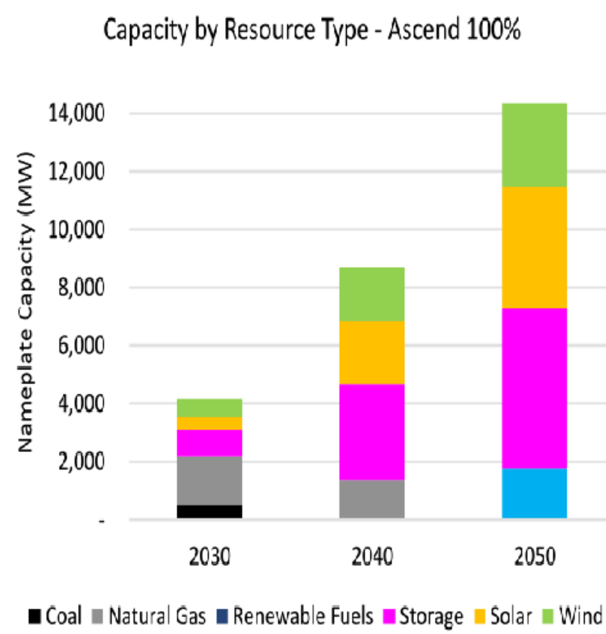




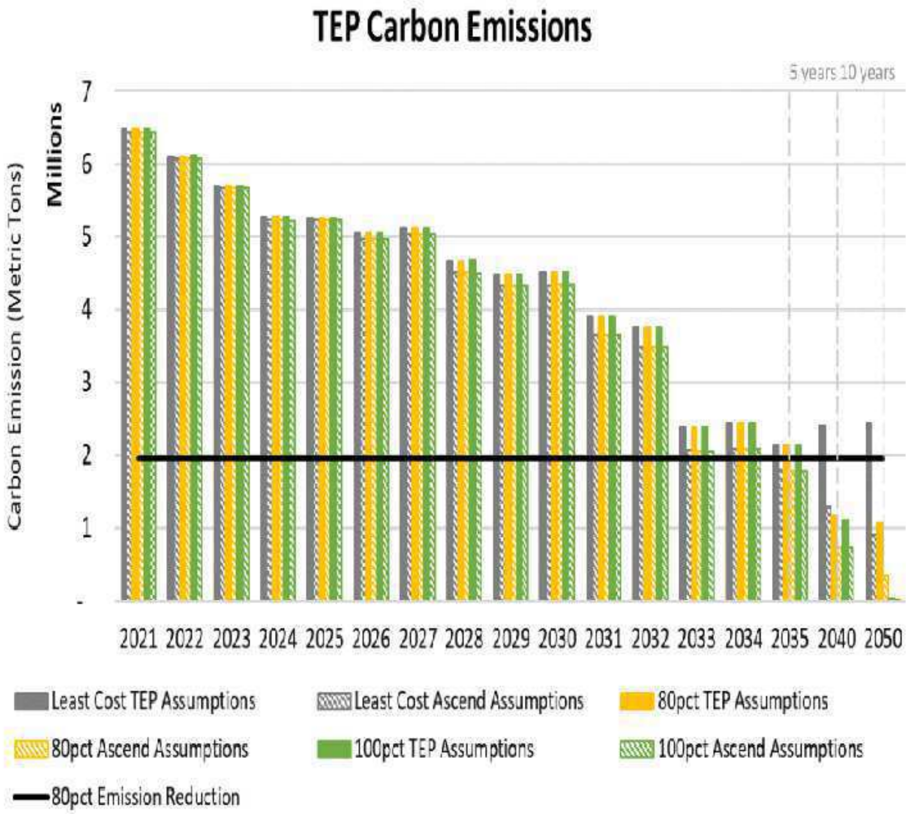


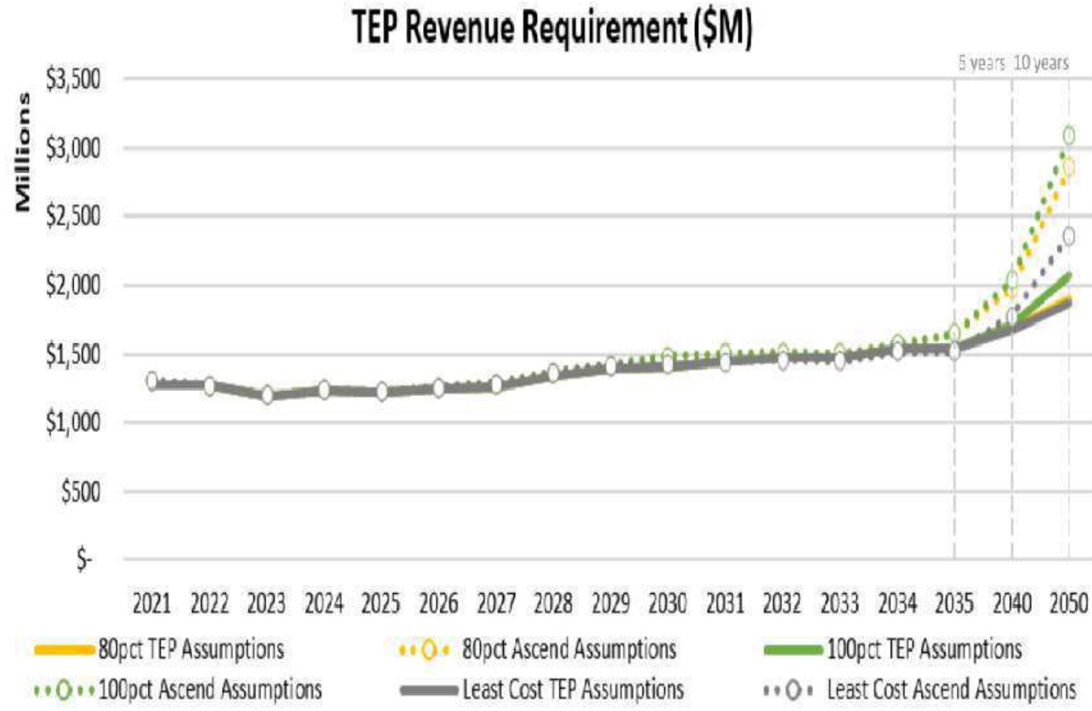






Energy Rules Results





- Each of the carbon constrained portfolios meet their targets
- The carbon emissions across portfolios remain similar through the mid 2030s
- The revenue requirements of 80% and 100% cases do not increase relative to the least cost portfolio until the mid 2030s

IRP Review for TEP (and UNSE)

- TEP worked with an advisory council consisting of customers, government, and advocacy groups to guide the IRP process
- The assumptions used by TEP/UNSE in the IRP are generally reasonable for technology costs and price shapes
  - The power and gas prices in the IRP are higher than both the Ascend and APS forecasts
- Ascend had the following suggestions to improve the TEP and UNSE modeling in the next IRP
  - Begin accounting for sub-hourly value of their resources
  - Study resource adequacy, reliability, and loss of load conditions in greater depth
  - Implement optimization software in its capacity expansion planning
  - Consider using a model which simulates weather, load, and market prices

UNSE

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UNSE Portfolios Modeled for Energy Rules Analysis: Capacity

Portfolios Designed Using TEP/UNSE Assumptions*

	UNSE Least Cost			UNSE Energy Rules 80%			UNSE Energy Rules 100%		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Natural Gas	383	383	408	383	383	383	383	138	-
Coal	-	-	-	-	-	-	-	-	-
Nuclear	-	-	-	-	-	-	-	-	-
Solar	210	270	370	290	370	590	290	370	590
Wind	60	165	275	245	335	535	250	380	535
Geothermal	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-
Storage (4 hours)	60	70	10	60	70	10	60	70	10
Storage (8 hours)	-	-	-	40	100	450	40	100	450
Storage (12 hours)	-	-	-	-	-	-	-	-	-
Microgrid	-	-	-	-	-	-	-	-	-
Market Purchases	-	-	-	-	-	-	-	-	-
Renewable Fuels	-	-	-	-	-	-	-	245	383

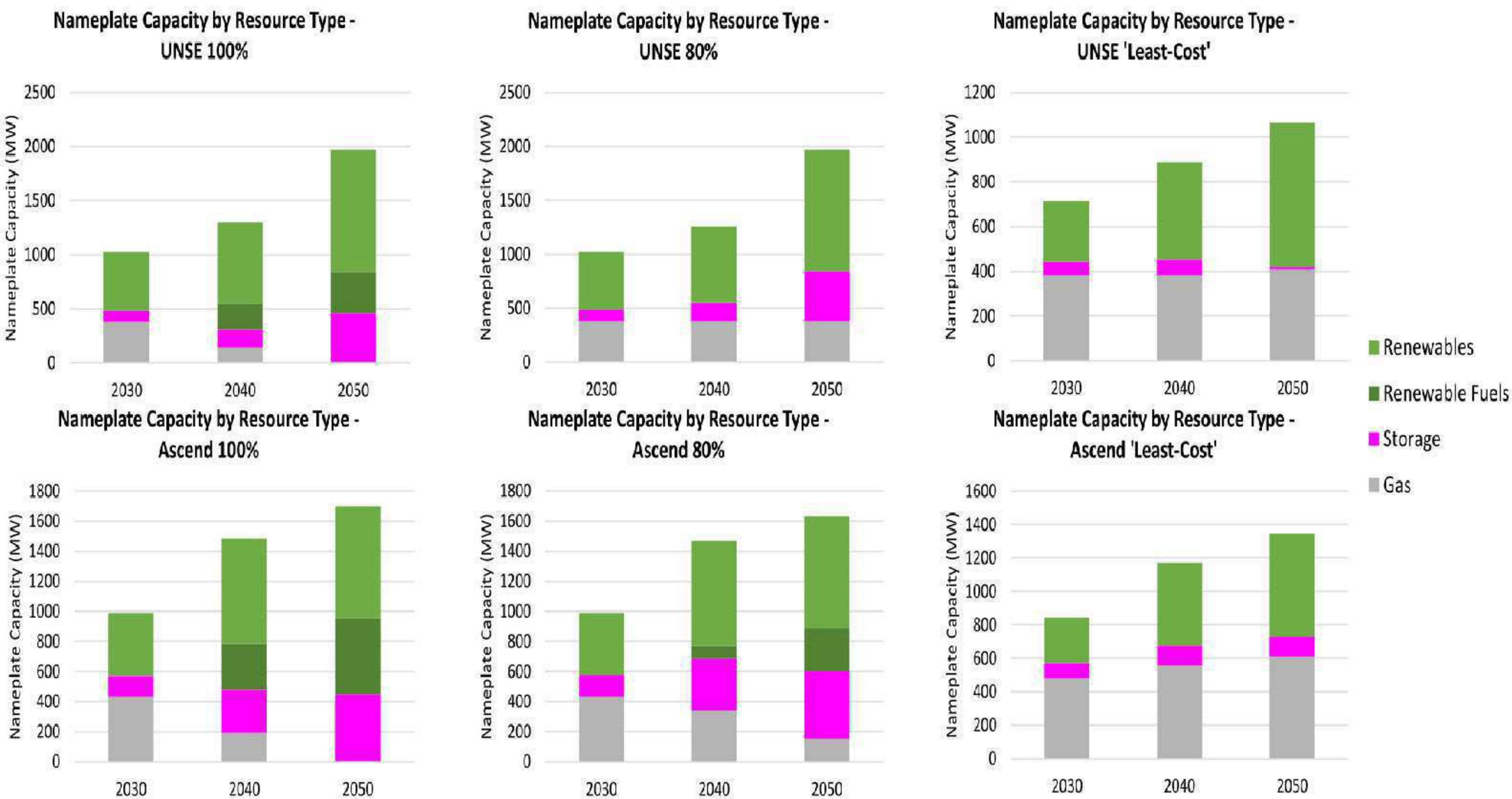
Portfolios Designed Using Ascend Assumptions

	Ascend Least Cost			Ascend Energy Rules 80%			Ascend Energy Rules 100%		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Natural Gas	483	558	608	433	343	150	433	193	-
Coal	-	-	-	-	-	-	-	-	-
Nuclear	-	-	-	-	-	-	-	-	-
Solar	210	320	370	261	370	395	261	370	395
Wind	60	175	250	156	325	350	156	325	350
Geothermal	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-
Storage (4 hours)	90	90	90	140	150	150	140	150	150
Storage (8 hours)	-	30	30	-	100	100	-	75	100
Storage (12 hours)	-	-	-	-	-	-	-	-	-
Storage (100 hours)	-	-	-	-	90	200	-	60	200
Microgrid	-	-	-	-	-	-	-	-	-
Market Purchases	-	-	-	-	-	-	-	-	-
Renewable Fuels	-	-	-	-	90	290	-	310	503

***Key Difference in Assumptions:**

- TEP/UNSE assumes a high-capacity contribution for solar that does not decline
- Ascend assumes the capacity contribution of solar generation approaches zero as the peak in net demand moves outside of daylight hours

UNSE Portfolios Modeled for Energy Rules Analysis: Capacity



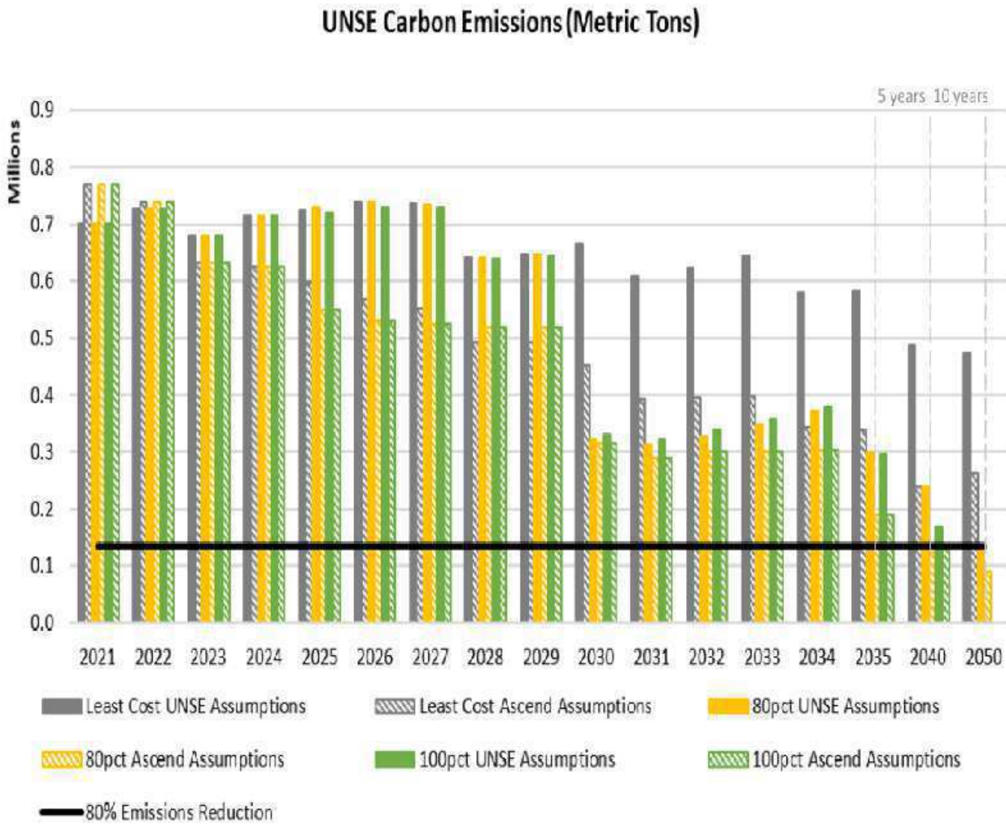
- 100% Portfolios:
  - Convert gas capacity to burn renewable fuels while also adding storage
- 80% Portfolios:
  - Keep gas capacity online to provide firm reliability while also adding storage

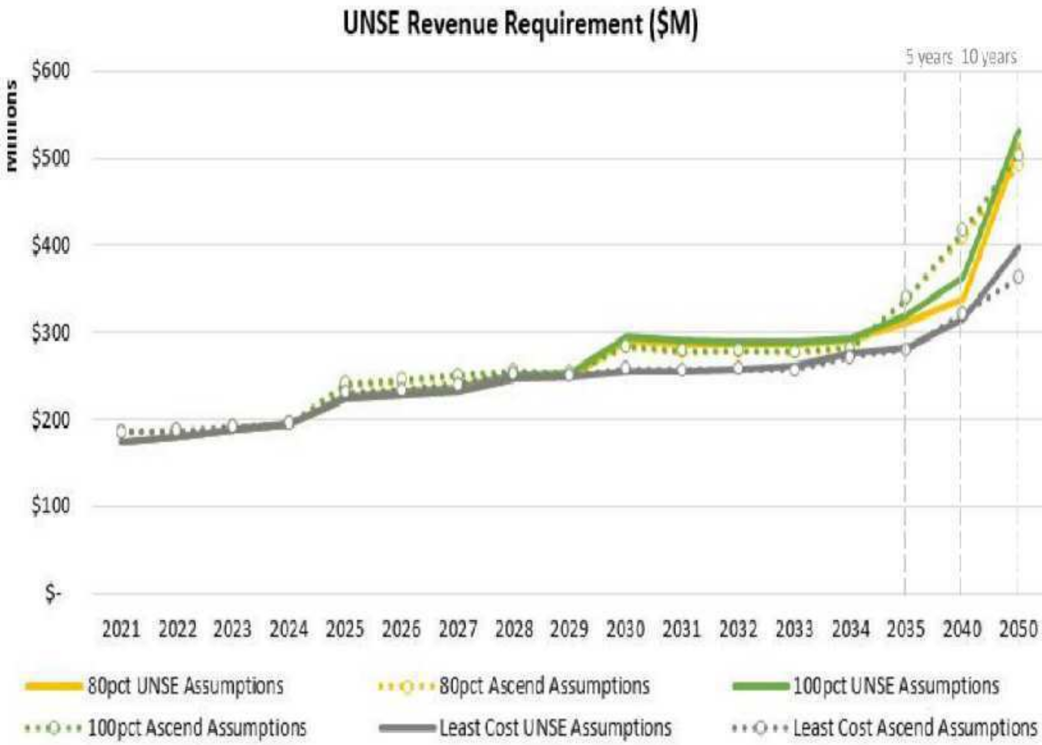
UNSE Portfolios Modeled for Energy Rules Analysis: Energy

- **100% Portfolios:**
  - Demand-side programs contribute substantially to overall energy
  - Energy losses in storage remain small part of overall energy supply
- **80% Portfolios:**
  - In Ascend assumptions, most emissions come from market interactions
  - Minimal gas contribution to overall energy supply even though gas capacity remains for reliability

"Renewables" includes generation from renewable fuels

UNSE Energy Rules Results: Emissions and Revenue Requirement

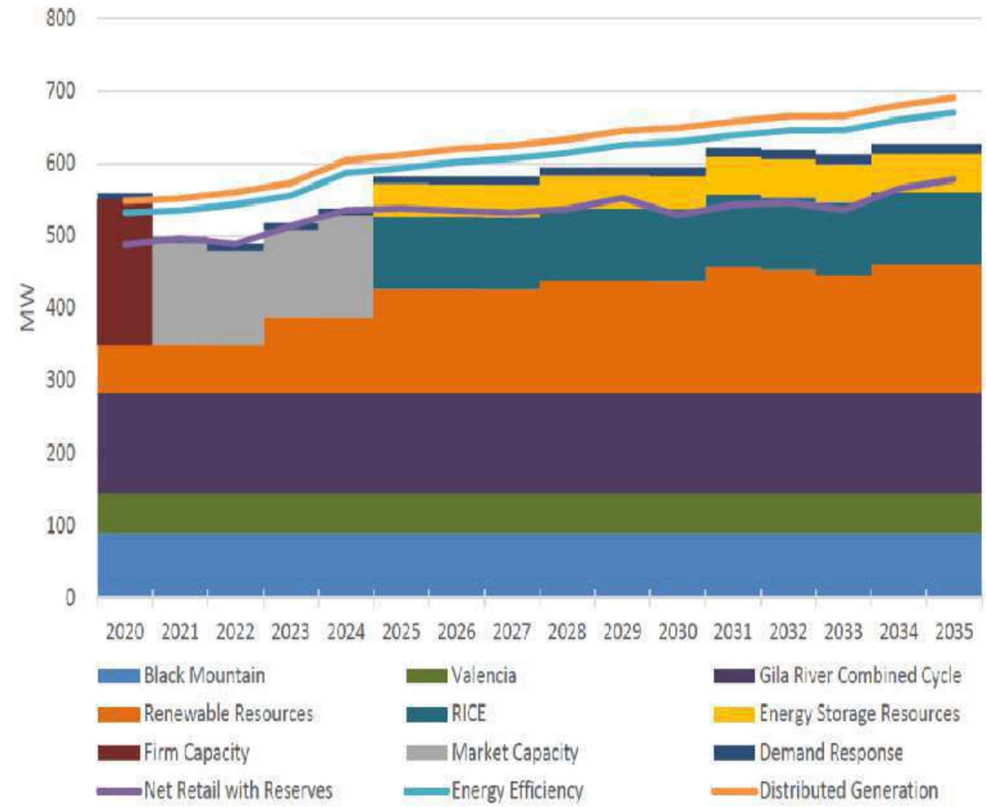




- Each of the carbon constrained portfolios meet their targets
- UNSE's immediate need for firm capacity makes meeting 2032 emissions reduction targets difficult without:
  - Running thermal generation at very low-capacity factors
  - Adding both short- and long-duration storage
  - Converting some thermal generation to run on renewable fuels
- Revenue requirements of the 80% and 100% remain similar to the 'least-cost' portfolio until the 2030s
  - Largest cost increases between the cases occur in the 2040s when future technologies and costs are unknown

IRP Review: UNSE Preferred Portfolio

- UNSE & TEP used the same assumptions and modeling approach (see TEP section for review of these)
- UNSE preferred portfolio
  - Keeps all existing thermal generation online
  - Adds 150MW solar, 115MW wind, 70MW storage, 100MW of RICE
  - 4% annual growth in demand response; energy efficiency generally consistent with draft energy rules
- Ascend's Review:
  - Reasonable path forward for reducing reliance on market capacity
  - Plan to use all-source RFPs will ensure lowest-cost procurement
  - RICE+Storage provides flexible capacity for reliability and compensation for renewable intermittency
  - Gila River NGCC plant economics relative to renewable generation should continue to be monitored
  - Future resource procurement should consider value of flexibility and system reliability, and consider all ownership structures



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Back Up Slides

Compliance with Decision 76632

Topic	Requirement
Natural gas storage	...Load Serving Entities, except Arizona Electric Power Cooperative, **shall address natural gas storage in greater detail in future IRPs**, including a discussion of efforts to develop natural gas storage, the costs and benefits of natural gas storage, and risks resulting from a lack of market area natural gas storage in Arizona. In addition, natural gas pricing issues are a key driver in future resource planning decisions by Arizona utilities. Thus a very robust sensitivity analysis, considering a wide variety of natural gas price scenarios, shall be a cornerstone of utility resource planning in Arizona. Consequently, the Load Serving Entities, except Arizona Electric Cooperative, **shall include a wide variety of natural gas price scenarios in future IRPs.**
Storage technologies	IT IS FURTHER ORDERED that all Load Serving Entities, except Arizona Electric Power Cooperative, shall include, in future Integrated Resource Plans, **an analysis of a reasonable range of storage technologies and chemistries**; and an analysis of anticipated future energy storage **cost declines** as further discussed in Decision No. 76295.
Storage and non-wires alternatives	IT IS FURTHER ORDERED that all Load Serving Entities, except Arizona Electric Power Cooperative, shall include **a storage alternative as a resource option in future Integrated Resource Plans**, and shall include an analysis of storage alternatives into their respective processes when considering **upgrades to transmission or distribution systems**, or when considering new build or capacity upgrades for existing generation resources.
Load growth	IT IS FURTHER ORDERED that Arizona Public Service Company shall prepare a report 4 justifying its 2015 and 2016 IRP load growth projections. Said report shall also include an analysis of (A) a "**no growth" scenario; and (B) a "low growth" scenario** (<1-percent growth) and the resultant implications on APS's resource selections under each scenario. APS shall also include a discussion regarding how each of the required scenarios affect its Three Year Action Plan. Said report shall be filed in the instant docket within 90 days of the Commission's decision in this matter.
	IT IS FURTHER ORDERED that all Load Serving Entities, except Arizona Electric Power Cooperative, shall include "**no-growth" and "low-growth (<1%)"** scenarios in future Integrated Resource Plans, until further order of the Commission

Compliance with Decision 76632

Topic	Requirement
Thermal as no more than 20% of new resource additions. Work with Tribal Nations	IT IS FURTHER ORDERED that Arizona Public Service Company, Tucson Electric Power Company, and UNS Electric, Inc. in each of their next IRPs shall analyze, along with their preferred portfolio, at **least one portfolio where the addition of fossil fuel resources is no more than twenty percent (20%) of all the resource additions**. In developing each of their portfolios to satisfy this requirement, Arizona Public Service Company, Tucson Electric Power Company, and UNS Electric, Inc. shall each work in good faith with each of the stakeholders in this case dirt desire to continue to **participate and also work in good faith with any Tribal Nations located in Arizona** that desire to participate in developing the portfolio to satisfy this requirement.
Clean energy resources portfolios	IT IS FURTHER ORDERED that Arizona Public Service Company, Tucson Electric Power Company, and UNS Electric, Inc., in each of their next IRPs shall analyze, along with their preferred portfolio, at least one portfolio that includes, as a Fifteen year forecast, all of the following: **the lesser of 1000 MW of energy storage capacity or an amount of energy storage capacity equivalent to 20% of system demand, at least 50% of "clean energy resources," which are resources that operate with zero net emissions beyond that of steam, of which 25 MW of nameplate capacity running at no less than 60% capacity factor are renewable biomass resources; and at least 20% of Demand Side Management.**

Analysis of Planning for Proposed Energy Rules

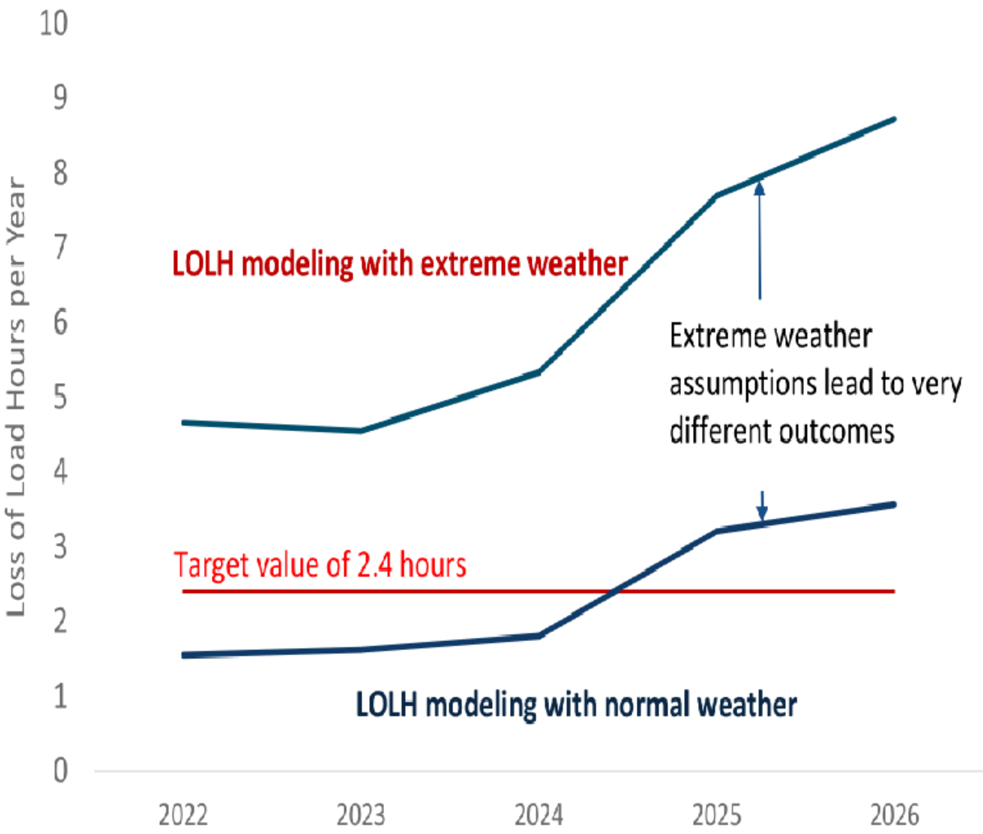
Section	Requirement	Review team lead
R14-2-2704 (B)	By January 1 2030, a Load-Serving Entities resource portfolio shall include a Demand-Side Resource Capacity equal to at least **35% of the Load-Serving Entities 2020 peak demand**;	Verdant
R14-2-2704 (B, 2, b)	Utilities must average at least **1.3% annual Energy Efficiency measured by megawatt-hour savings over the three-year planning period** without carrying over energy savings credits from programs implemented before January 1, 2021	Verdant
R14-2-2704 (B, 3)	Be December 31 2035, the installation of **Energy Storage Systems** with an aggregate capacity equal to **at least 5% of the Electric Utility's 2020 peak demand**, of which at least **40% shall be derived from Customer-owned or Customer-leased Distributed Storage;**	Ascend (grid scale) Verdant (BTM)
R14-2-2704 (B, 4)	A **100% reduction in Carbon Emissions below its Baseline Carbon Emissions Level** with the following corresponding interim standards: (2032 = 50% below, 2040 = 75% below, 2050 100% below)	Ascend
R14-2-2704 (E)	An Electric Utility's Baseline Carbon Emissions Level shall be the average annual metric tons of Carbon Emissions from all Generating Units used to meet the Electric Utility's retail kwh sales. during the consecutive three-calendar-year period of 2016 to 2018.	Ascend

Verdant Associates Focus Areas: Load Forecast and Demand Side Resources

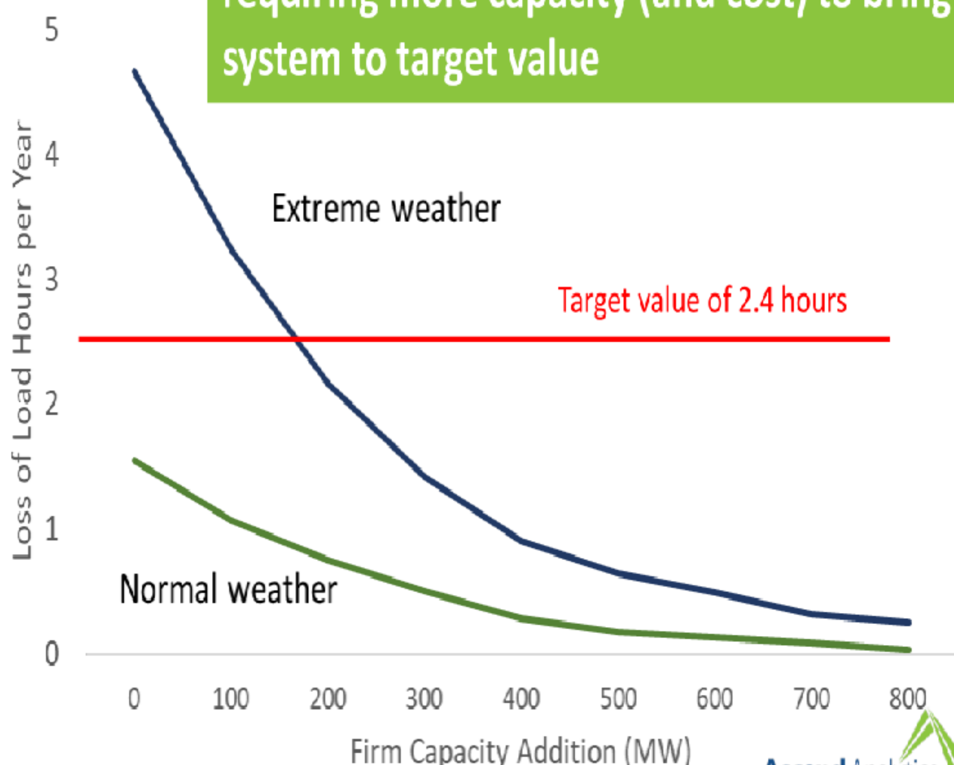
- **Demand Side Resources**
  - Energy Efficiency: measures, end-use mix, incremental costs and savings, adoption forecast, funding level
  - Demand Response / Rates: programs, participation levels, current and projected tariff mix, load impacts, AMI capabilities
  - Distributed Generation / Storage: programs, participation levels, market adoption, modeling approaches, cost projections
  - Building Decarbonization: sector end-uses, new construction vs. retrofit, cost projections, programs
  - Transportation Decarbonization: charging infrastructure investments, market forecast, current and forecasted adoption, grid impacts
- **Load Forecast**
  - Methods, data sources, assumptions, and general model specifications
    - Level of aggregation, gross versus net load
    - Time series versus econometric modeling
    - Assumptions about building/transportation electrification, energy efficiency, and demand side resources
  - Key drivers
    - Population size/growth, end-use service demand, technology saturations, fuel shares, new construction
    - Consumption per capita/unit
- **Integration / Interactions**

Example of Extreme Weather Resource Adequacy Modeling

- Utility sees that typical weather simulations based on recent history show an adequate system for the next 3 years
- To test reliability in extreme conditions adjustments are made
  - Increased volatility in weather simulations leads to colder days in winter and hotter days in summer with more extreme loads
  - Adding temperature dependent forced outages to thermal generation and renewables when temperatures drop below a threshold
  - Ensuring longer duration of extreme temperatures



Result is higher modeled LOLH values requiring more capacity (and cost) to bring system to target value



A solar heavy system is challenging with short duration storage

- The high amount of energy storage moves significant levels of renewables from daytime hours to evening hours.
- Energy storage moves excess renewable energy during the day to double the percentage of load served in the evenings
- This is a California based example

Stored energy is used in the evening

2040 **WITH** Energy Storage

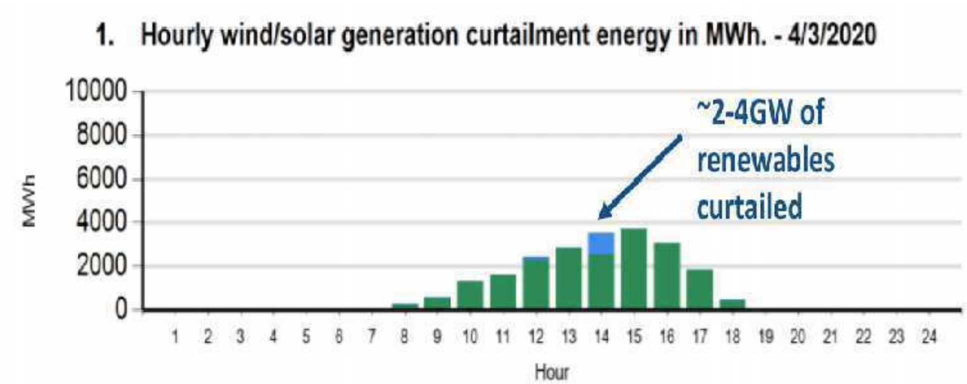
Jan	57%	57%	57%	60%	64%	69%	68%	65%	100%	100%	100%	100%	100%	100%	100%	100%	100%	53%	58%	66%	66%	64%	63%	61%
Feb	56%	57%	59%	62%	68%	71%	68%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	55%	55%	56%	55%	55%	57%	57%
Mar	59%	64%	68%	74%	82%	83%	74%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%	58%	59%	56%	56%	58%	59%
Apr	62%	65%	69%	75%	80%	80%	74%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	58%	60%	56%	55%	57%	60%
May	56%	61%	63%	66%	68%	69%	67%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	55%	58%	53%	52%	54%	56%
Jun	54%	53%	53%	55%	59%	63%	58%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%	61%	68%	64%	61%	59%	58%
Jul	44%	44%	44%	45%	49%	51%	49%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	96%	68%	68%	61%	57%	53%	46%
Aug	45%	46%	47%	48%	52%	59%	58%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	94%	74%	72%	63%	57%	53%	47%
Sep	46%	46%	46%	49%	53%	63%	64%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	87%	69%	69%	62%	58%	55%	50%
Oct	62%	59%	59%	61%	67%	74%	74%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	71%	75%	77%	72%	69%	68%	69%
Nov	66%	63%	62%	67%	75%	84%	82%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	76%	77%	81%	78%	76%	76%	74%
Dec	63%	59%	59%	61%	69%	79%	77%	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%	70%	70%	79%	78%	75%	75%	72%

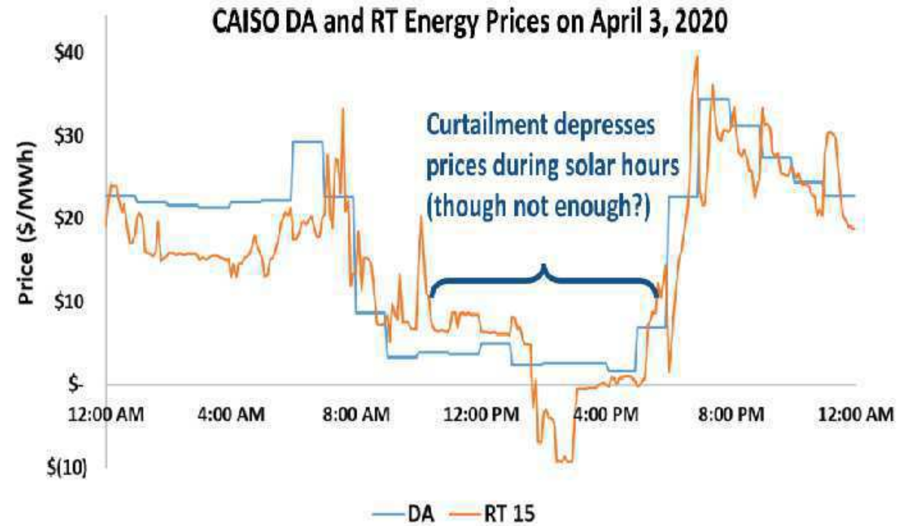
2040 **WITHOUT** Energy Storage

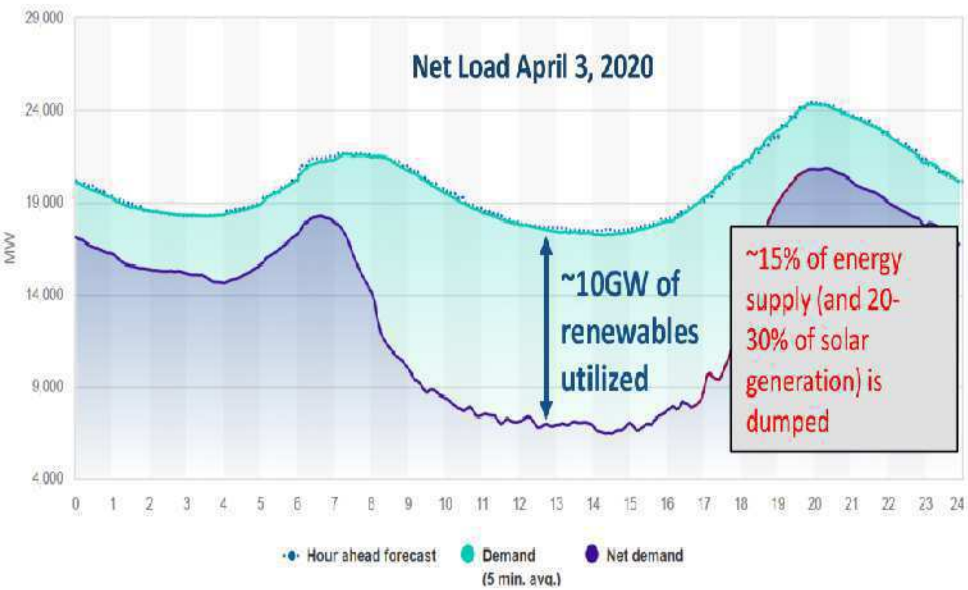
Jan	54%	60%	63%	66%	67%	62%	56%	54%	100%	100%	100%	100%	100%	100%	100%	100%	100%	39%	38%	39%	38%	41%	46%	50%
Feb	53%	57%	63%	64%	64%	61%	55%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	42%	39%	39%	39%	41%	44%	48%
Mar	55%	64%	69%	77%	76%	69%	59%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	41%	38%	37%	39%	43%	49%
Apr	56%	62%	68%	75%	75%	68%	63%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	43%	40%	36%	37%	41%	47%
May	50%	57%	62%	65%	64%	61%	58%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	45%	42%	37%	37%	40%	45%
Jun	43%	47%	51%	54%	54%	53%	51%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	40%	39%	35%	35%	36%	40%
Jul	42%	45%	48%	51%	52%	50%	49%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	90%	38%	38%	34%	34%	35%	38%
Aug	44%	49%	53%	56%	57%	56%	53%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	83%	35%	34%	32%	32%	35%	39%
Sep	40%	44%	48%	51%	52%	50%	48%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	35%	33%	31%	31%	33%	37%
Oct	49%	52%	57%	60%	60%	56%	51%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	40%	38%	35%	34%	36%	38%	43%
Nov	55%	60%	64%	66%	67%	63%	58%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	38%	37%	37%	38%	40%	44%	49%
Dec	50%	54%	56%	59%	59%	57%	53%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	40%	39%	40%	39%	41%	44%	47%

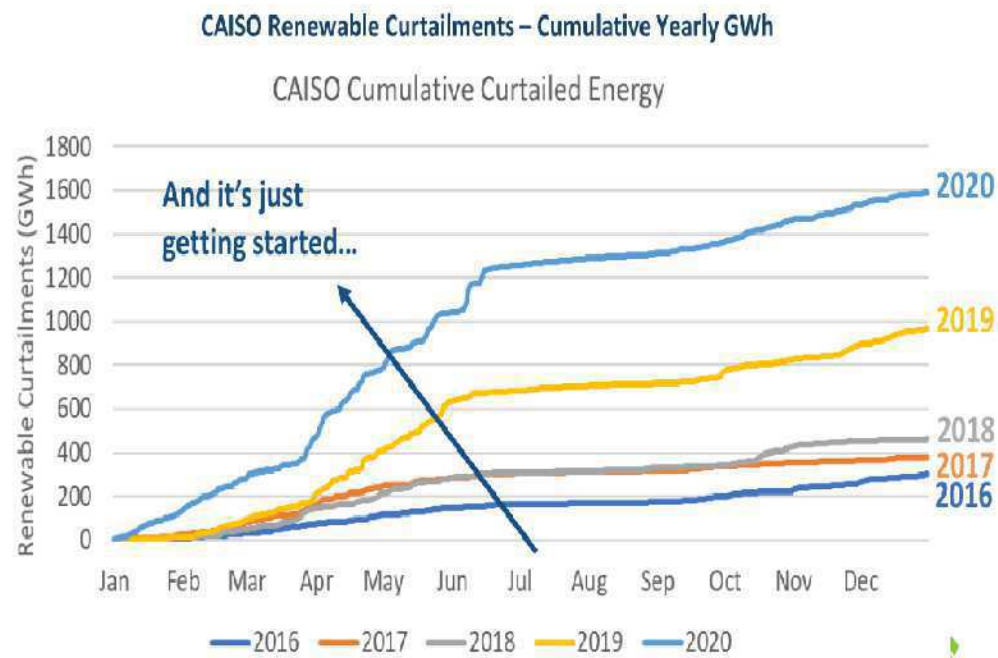
Curtailed Power and Renewable Penetration

- CAISO economic curtailments rapidly increasing due to zero or negative prices

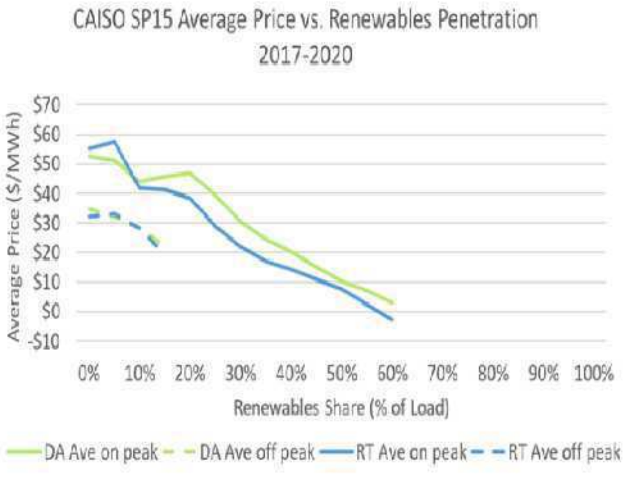


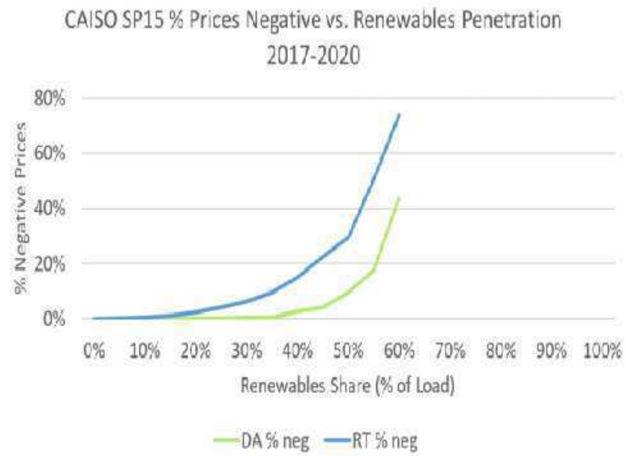


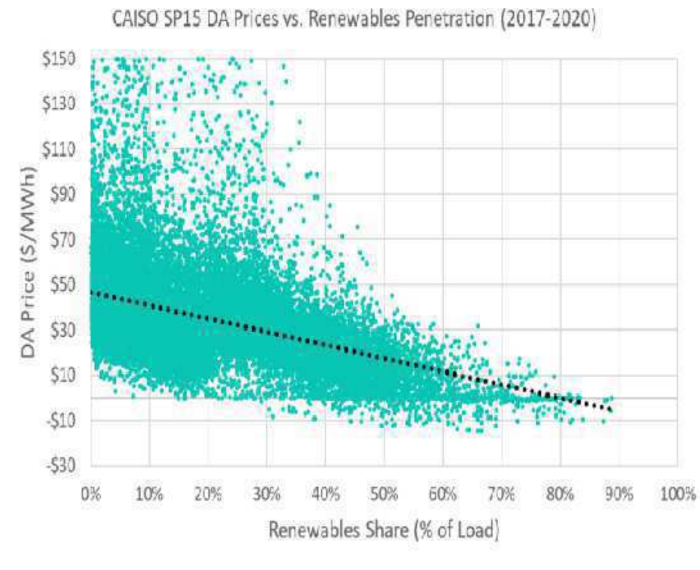




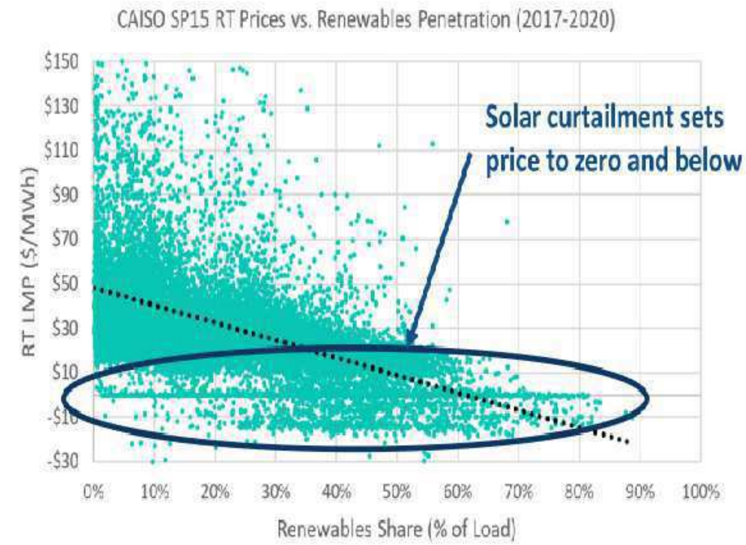
Price Depression as Renewable Penetrations Rise





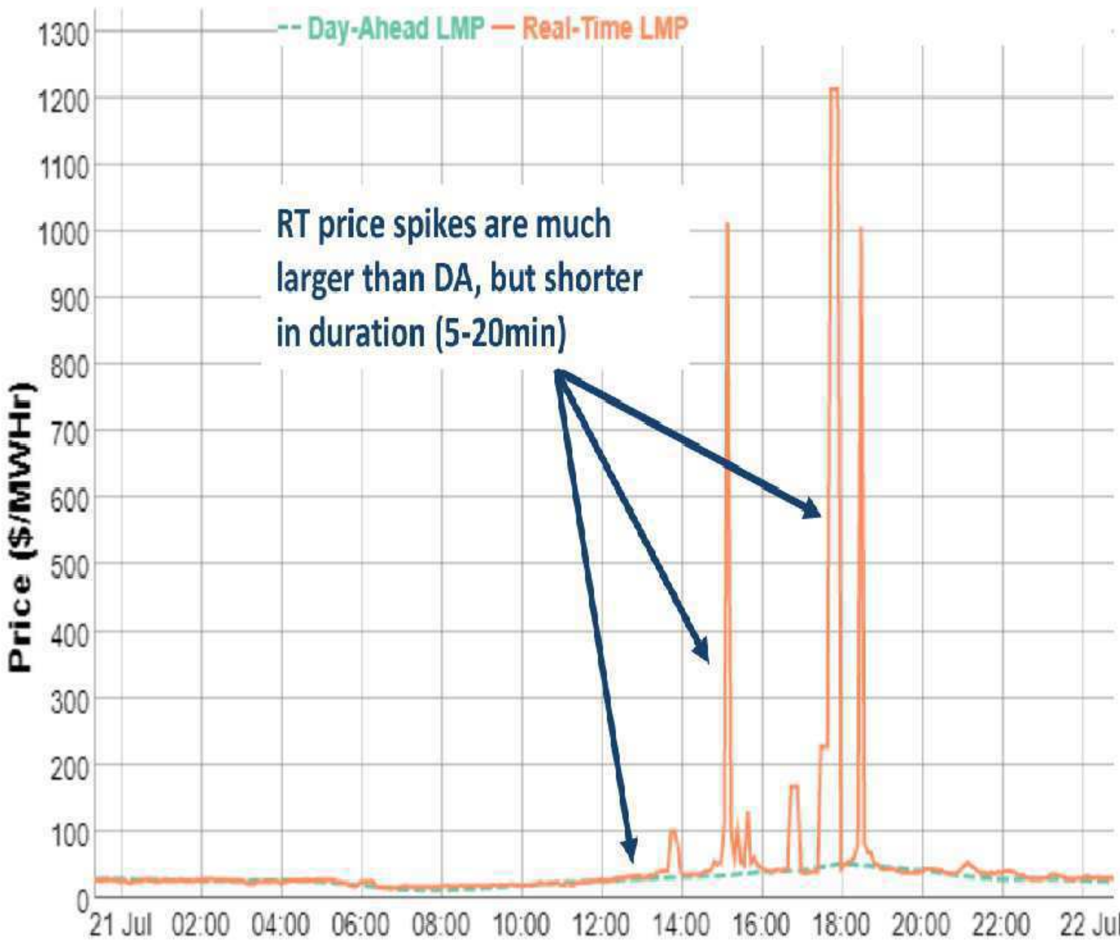


- Price depression at high renewables penetration appears in both real-time and day-ahead markets, on-peak and off-peak
- Negative prices and renewable curtailment grow as renewables shares climb above ~25%, then rapidly accelerate at penetrations above 50%
- *But it's not just the average that is affected by renewables...*



Price Volatility Increases as Renewable Penetration Rises

Day-ahead and Real-time Prices July 21, 2019



Year	Renewable Penetration	Positive RT Price Spike Events	Negative RT Price Spikes Events
2015	11%	1,028	5,462
2016	14%	1,801	6,648
2017	17%	2,225	6,717
2018	19%	3,086	4,011
2019	22%	2,643	4,653

Importance of price spikes:

- Occur ~1.5% of time
- Represent 22% of average price and 30% of retail costs because of demand coincidence
- Create incentive to hedge load in the day-ahead market, resulting in a DA-RT price spread
- Increasing intermittent renewables are driving up both RT and DA volatility

Ascend Analytics

On-Peak is the New Off-Peak

- **On-peak and off-peak power prices will invert over time with increasing solar deployment**
  - Solar-heavy resource mix depresses prices during on-peak hours (under current peak period definition)
  - Solar curtailment will increasingly lead to zero/negative on-peak prices
  - Off-peak **renewable** generation is much more expensive than solar
  - Off-peak **non-renewable** generation variable cost rises with carbon prices